Idaho Department of
Environmental Quality

MIXING ZONE TECHNICAL PROCEDURES MANUAL

DRAFT

August 2008

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CONTENTS

FIGURES

TABLES

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ACRONYMS

BA/BE	biological assessment/biological evaluation
BAF	bioaccumulation factor
BCF	bioconcentration factor
BHC	hexachlorocyclohexane
BURP	Beneficial Use Reconnaissance Program
CAD	computer-aided design
CCC	Criteria Continuous Concentration
CEAM	Center for Exposure Assessment Modeling
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMC	Criteria Maximum Concentration
CWA	Clean Water Act
ºC	degrees Centigrade
ºF	degrees Fahrenheit
DNA	deoxyribonucleic acid
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Idaho Department of Environmental Quality
DFG	Idaho Department of Fish and Game
DKHW	Davis, Kannberg, and Hirst model for Windows
EFDC	Environmental Fluid Dynamics Code
EFH	Essential Fish Habitat
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
ft	feet
gpm	gallons per minute
HEC-RAS	Hydrologic Engineering Centers River Analysis System
IBI	index of biological integrity
IDAPA	Idaho Administrative Procedures Act
IDF&G	Idaho Department of Fish and Game
IRIS	Integrated Risk Information System
LC_{50}	lethal concentration fifty
LOEC	lowest observed effects concentration
m	meter
MDNF	momentum-dominated near-field
MGD	million gallons per day
mg/L	milligrams per liter
ml	milliliter
m/s	meters per second

MSA	Magnuson Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observed effects concentration
NPDES	National Pollutant Discharge Elimination System
NRFIELD	near field model
NTU	nephelometric turbidity unit
1Q10	1-day, 10-year minimum statistical flow value
ORW	Outstanding Resource Water
PAH	polycyclic aromatic hydrocarbon
PBT	persistent, bioaccumulative, and toxic
PCB	poly-chlorinated biphenyl
PCDD	polychlorinated dibenzo-dioxin
PCDF	polychlorinated dibenzo-furan
PDS	Prych, Davis, and Shirazi surface discharge model
PEC	potency equivalency concentration
POTW	publicly owned treatment works
QA/QC	quality assurance/quality control
RDI	river diatom index
RfD	reference dose
RFI	river fish index
RPA	reasonable potential analysis
RPTE	reasonable potential to exceed
RSB	Roberts, Snyder, and Baumgartner length scale model
s	second
7Q10	7-day, 10-year minimum statistical flow value
SDI	stream diatom index
SFI	stream fish index
SIC	standard industrial classification
SRW	Special Resource Water
2,3,7,8-TCDD	tetrachlorodibenzo-p-dioxin
T	temperature
TBEL	technology-based effluent limitation
TCMC	Thompson Creek Mining Company
30Q5	30-day, 5-year minimum statistical flow value
TIE	toxicity identification evaluation
TMDL	total maximum daily load
TRE	toxicity reduction evaluation
TSD	EPA’s Technical Support Document (see references)
TUa	Toxic Unit-Acute
TUc	Toxic Unit-Chronic
TU	Toxic Unit
UDKHDEN	updated Davis, Kannberg, and Hirst density model

µg/L	micrograms per liter (also parts per billion [ppb])
µmho/cm	micromhos per centimeter
UM	updated merge model
UM3	three-dimensional updated merge model
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
VP	Visual Plumes
WET	whole effluent toxicity
WQBEL	water quality-based effluent limitation
ZID	zone of initial dilution

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1.0 INTRODUCTION

1.1 Purpose of Manual

This technical procedures manual provides guidance to Idaho Department of Environmental Quality (DEQ) staff and members of the public in designing mixing zones which are compliant with Idaho's water quality standards. Topics specifically addressed include:

- how to conduct a biological, chemical, and physical appraisal
- how to account for data limitations
- how to determine the appropriate model for calculating the size of a mixing zone
- how to select model input values

This manual provides advice on analysis techniques as they apply to mixing zone applications in Idaho. The information in this document is intended to be dynamic and should be updated based on practical experience as more information and viable techniques become available. Dilution predictions or modeling analyses other than those outlined in this technical procedures manual may also be approved by DEQ.

This document does not have the force and effect of a rule and is not intended to supersede statutory or regulatory requirements. It is provided as general guidance and does not alter the discretionary authority of DEQ when it makes a mixing zone decision.

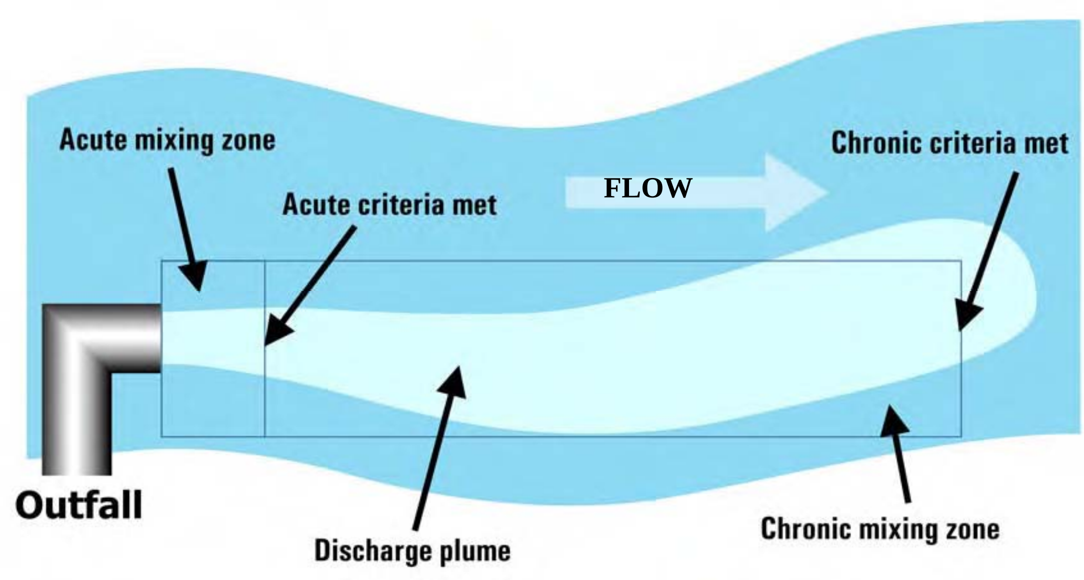
1.2 Mixing Zone Definition

Wastewater effluent that is discharged to surface water mixes with and is diluted by the receiving water at varying rates that depend on a number of factors. Pollutants originating in the discharge will become less concentrated as the discharge mixes with the receiving water, entraining more and more of the receiving water until becoming fully mixed. A mixing zone is defined in the U.S. Environmental Protection Agency's (EPA's) Technical Support Document (TSD) for Water Quality-based Toxics Control (EPA 1991) as the area of a water body in which acute and chronic water quality standards or criteria may be exceeded as long as acutely toxic conditions are prevented. Similarly, Idaho water quality standards (Idaho Administrative Procedures Act [IDAPA] 58.01.02) define a mixing zone as a defined area or volume of a receiving water surrounding or adjacent to a wastewater discharge where the receiving water, as a result of the discharge, may not meet all applicable water quality criteria. It is a place where wastewater mixes with receiving water for dilution and not a place where effluents are treated.

EPA's TSD can be downloaded from http://www.epa.gov/npdes/pubs/owm0264.pdf. (Note that this is a large file, which may download slowly.)

It is important to recognize that the term mixing zone is a regulatory construct, an imaginary line around a discharge plume within which water quality criteria can be exceeded. This is separate from the physical discharge plume, which consists of the area where effects of the discharge can be measured in the receiving water. Figure 1 illustrates the difference between a mixing zone and a physical discharge plume.

Figure 1. Mixing Zones and Discharge Plumes



Mixing zone analysis is not an exact science, and most often relies upon model results to provide an estimate of the potential size of the area that could exceed water quality criteria. The formulae and algorithms used in mixing zone models are conservative, and conservative assumptions should be made in determining model inputs. As such, the actual dilution will likely be more rapid than the calculated value. Data inputs for mixing zone analyses will vary depending upon discharge and ambient conditions. Often there is limited ambient data, especially data related to the hydrographic characteristics of the receiving water. Most often site-specific data will need to be collected; however, because of difficulties or expense to collect ambient data, it may be necessary for the modeler to use "best estimate" values.

1.3 Mixing Zone Applicability and Use in NPDES Permits

In order to protect the integrity of a receiving water body, it is not always necessary to set the effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits equal to water quality criteria. Under federal regulations implementing the Clean Water Act (CWA), states may allow mixing zones in receiving waters where numeric water quality criteria can be exceeded, as long as beneficial uses are protected. However, it must be ensured that there will be no short-term acute toxic effects, long-term chronic toxic effects, or human health effects from discharges. Although EPA

Nonpoint source activities are activities in a geographical area where pollutants are dissolved or suspended in water that is applied to or incident on the area and subsequently discharged to waters of the State (not through a discrete conveyance). EPA does not issue permits for nonpoint source discharges in Idaho and, generally, they do not require mixing zone authorizations.

is responsible for issuing NPDES permits in Idaho, only DEQ has authority to grant a mixing zone.

A mixing zone analysis is used to determine how much dilution, if any, a receiving water body can provide. Dilution of the effluent is an allowable factor (40 Code of Federal Regulations [CFR] 122.44(d)(1)(ii)) that can be incorporated into an analysis to determine if there is "reasonable potential" for the discharge to cause or contribute to an exceedance of water quality criteria. This is known as a reasonable potential analysis (RPA). If no reasonable potential exists, then technology-based effluent limitations (TBELs) will be set. If reasonable potential does exist, then water quality-based effluent limitations (WQBELs) must be calculated. Effluent limitations will be the more stringent of the TBELs or the WQBELs.

To determine reasonable potential, EPA follows the recommended approach as defined in the TSD. This approach uses maximum projected effluent concentrations, background concentrations, and the dilution factor as determined in the mixing zone analysis (e.g., 10% of the critical low flow) to project a maximum receiving water concentration at the boundary of the mixing zone. If this concentration exceeds the most stringent applicable water quality criterion, reasonable potential is shown and WQBELs are required for the specific pollutant. Note that EPA may consider other factors in determining reasonable potential, even if the most stringent criteria are not shown to be exceeded.

After EPA determines that there is reasonable potential, permit limits must be calculated. This is accomplished by applying the aquatic life and human health water quality criteria at the mixing zone boundary and using the dilution factor to determine end-of-pipe limits for each pollutant according to the TSD approach. Note that the TSD approach also takes into account the variability in discharge composition, the nature of the criteria, and the sampling frequency to ensure that the water quality criteria will not be exceeded outside of the mixing zone. The TSD was written to specifically address toxic pollutants for which acute and chronic criteria were developed. Its procedures are not wholly appropriate for other pollutants such as phosphorus, sediment, bacteria, or temperature.

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2.0 MIXING ZONE RULES

Federal regulations implementing the CWA and EPA guidance largely defer to the states in establishing the specific requirements of their mixing zone regulations. States have taken advantage of this flexibility by adopting a variety of mixing zone rules and requirements. Idaho water quality standards prohibit any discharges the will injure designated or existing beneficial uses (IDAPA 58.01.02.080) of the receiving water body. In order to protect beneficial uses of the receiving water body, IDAPA 58.01.02.060 provides key considerations that DEQ must take into account when determining whether a mixing zone is appropriate. This section summarizes the key components of Idaho's mixing zone rules. Appendix A includes each provision of IDAPA 58.01.02.060 and other related sections of Idaho's water quality standards, as well as a cross-reference to where they are discussed in this manual.

"After a biological, chemical, and physical appraisal of the receiving water and the proposed discharge and after consultation with the person(s) responsible for the wastewater discharge, the Department will determine the applicability of a mixing zone and, if applicable, its size, configuration, and location" (IDAPA 58.01.02.060).

A key aspect of Idaho's rules (IDAPA 58.01.02.060) is that a biological, chemical, and physical appraisal be conducted of the receiving water body for which a mixing zone is requested. The purpose of this appraisal is to evaluate the potential impact of the mixing zone on the beneficial uses of the receiving water body. Idaho's mixing zone rules specifically provide that a mixing zone should be located so it does not cause unreasonable interference with or danger to existing beneficial uses. DEQ interprets unreasonable interference with beneficial uses to include, but is not limited to, blocking fish migration, causing acute lethality or public swimming beach closures, enticing organisms to spend prolonged periods in the mixing zone, or inhibiting recreation by creating a physical hazard to boaters or swimmers. The evaluation of a mixing zone should include consideration of the types of compounds and substances to be discharged and the potential effects of those pollutants as well as the discharge configuration on the chemical, biological, and physical condition of the receiving water body. Only those mixing zones that are determined to not unreasonably interfere with the beneficial uses of the water body can be allowed. Furthermore, mixing zones should be as small as practical and should only be authorized when meeting water quality criteria at the end of the pipe is technologically or economically infeasible.

To perform a mixing zone analysis, it is important to understand the nature and application of water quality standards and criteria. Section 2.1 of this manual provides background information on water quality standards and criteria. Sections 2.2 and 2.3 specifically discuss how to consider effects of mixing zones on beneficial uses, particularly human health and aquatic life. Section 2.4 summarizes information on chemical analyses. IDAPA 58.01.02.060.01(e) and (f) describe size limitations for mixing zones; information on determining compliance with these provisions is presented in Section 2.5. Section 2.6 briefly describes IDAPA 58.01.02.060.01(a), which indicates that DEQ should consider the use of a submerged pipe, conduit, or diffuser in authorizing mixing zones. Section 2.7 discusses IDAPA 58.01.02.060.02, which addresses mixing zones for Outstanding Resource Waters (ORWs).

Table 1 includes the key questions that should be addressed in mixing zone evaluations.

Table 1. Summary of Key Questions for Mixing Zone Evaluations

Key Mixing Zone Questions	Further Information
Does the receiving water meet criteria for pollutants in the proposed discharge?	If yes, then proceed with mixing zone analysis. If no, then a mixing zone is generally not allowed (e.g., receiving water is impaired for pollutants in the proposed discharge).
What are the existing uses of the water body for which a mixing zone is proposed?	List uses.
What is the existing, designated, or presumed aquatic life use(s) of the water body?	Describe the aquatic life use(s) and list the appropriate aquatic life numeric criteria for all constituents in the effluent for which a mixing zone is proposed.
Is the water body designated as a Domestic Water Supply?	If yes, list the human health-based numeric criteria for consumption of water and organisms for all constituents in the effluent for which a mixing zone is proposed. If no, there is no need to evaluate the mixing zone for human health-based numeric criteria for consumption of water and organisms.
Is contact recreation an existing, designated, or presumed use of the water body?	If yes, describe the public access to the mixing zone area, the extent of the mixing zone, and the seasonality of public use. For discharges from municipal treatment plants, also describe expected *E. coli* concentrations within the mixing zone. If no, there is no need to consider recreational uses.
Will the mixing zone impact critical habitat for Endangered Species Act (ESA)-listed species?	If yes, describe the likely impact, spatial and temporal extent of the impact, and all species and life stages impacted. If no, describe all habitat features that may be altered by the mixing zone, the extent of these impacts, and any associated adverse impacts to other aquatic life in the vicinity of the proposed mixing zone.
What is the extent of the mixing zone and the magnitude, duration, and frequency of pollutant exposure?	Describe the proposed mixing zone's spatial and temporal characteristics.
Will the effluent contain substances known to be toxic to aquatic life?	If yes, describe all potential toxic substances, predicted concentrations within the mixing zone, and sensitivity of the aquatic community in the vicinity of the mixing zone (especially species and/or life stages of special concern). If no, go to the next question.
Will the effluent include chemicals known or predicted to bioaccumulate or bioconcentrate?	If yes, list these compounds and describe their predicted concentration in the mixing zone and the potential impact on the food web. In addition, discuss the assimilative capacity of the receiving system and proposed monitoring efforts for impacts from discharge of such compounds. If no, go to the next question.
Will the effluent contain any known carcinogens, mutagens, or teratogens?	If yes, evaluate the predicted concentrations within the mixing zone, the potential for human contact with the mixing zone, and/or consumption of contaminated fish. If no, go to the next question.
Does the aquatic community in the vicinity of the proposed mixing zone at any time of the year contain ESA-listed species or species of special concern?	If yes, describe the populations of all ESA-listed species or species of special concern within the water body and potential impacts to these species from the proposed mixing zone. If no, go to the next question.

Table 1, continued

Key Mixing Zone Questions	Further Information
Will the mixing zone contain any constituents known to elicit an avoidance behavior?	If yes, list these constituents and the likely species affected and describe the spatial and temporal extent of the mixing zone and extent of the zone of passage. If no, describe the zone of passage for the mixing zone and any potential to interfere with local or migratory fish movements.
Does salmonid spawning occur within the proposed mixing zone area?	If yes, evaluate the potential of the proposed mixing zone to adversely impact salmonid spawning, or relocate the mixing zone. If no, go to the next question.
Are fish likely to be harvested from the water body in the vicinity of the mixing zone area?	If yes, describe all effluent constituents that have the potential to bioaccumulate or cause organoleptic impacts. If no, go to the next question.
Are acute and/or chronic water quality criteria predicted to be exceeded in the mixing zone?	If yes, describe the spatial extent of such exceedances and discuss whether acutely toxic conditions will exist. Concentrations of any substance predicted to exceed 96-hour lethal concentration fifty (LC_{50}) for any biota significant to the receiving water are prohibited. If no, go to the next question.
Is the mixing zone as small as practicable?	If yes, provide documentation supporting such a determination If no, re-evaluate the mixing zone size, effluent limitations, and treatment capabilities of the facility.
Is there a sampling and monitoring protocol set up that will adequately characterize the pre-discharge physical, chemical, and biological condition of the water body, as well as all post-discharge impacts from the proposed mixing zone?	If yes, describe the sample protocol (for pollutants and the biological community) in detail, including all spatial and temporal aspects of the monitoring and quality assurance/quality control (QA/QC) procedures. If no, a sampling and monitoring protocol may be developed for the mixing zone, or sufficient information should be submitted that describes why sampling and monitoring are not needed.

2.1 Water Quality Standards

Section 101(a) of the CWA states in part that wherever attainable, waters must achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable").

In order to achieve this goal, states are required to adopt water quality standards to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. A water quality standard defines the water quality goals of a water body by designating the beneficial use or uses to be made of the water (e.g., salmonid spawning and/or drinking water supply), by setting criteria necessary to protect the uses, and by preventing degradation of water quality through antidegradation provisions. Critical to the evaluation and authorization of mixing zones are the application of appropriate water quality standards. Idaho has twelve beneficial use designations, which are listed in IDAPA 58.01.02.100. Idaho also has narrative and numeric criteria in Sections 200 through 253 of the water quality standards (IDAPA 58.01.02). Narrative criteria apply to all water bodies, regardless of their beneficial use. Numeric criteria are use-specific and are developed to protect either aquatic life or human health.

2.1.1 Narrative Criteria

There are nine narrative criteria (also known as "general" criteria) in Idaho's water quality standards. Water quality in mixing zones must meet the applicable narrative criteria; therefore, mixing zones must be free from the following materials in concentrations or quantities that impair beneficial uses:

- hazardous materials
- toxic substances
- deleterious materials
- radioactive materials (in concentrations that exceed the values listed in 40 CFR.10.1.20)
- floating, suspended, or submerged matter
- excess nutrients
- oxygen-demanding materials
- sediment

2.1.2 Numeric Criteria

Numeric criteria are use-specific; thus, the beneficial use of the receiving water body must be known in order to appropriately evaluate a mixing zone. The most stringent of all applicable use-specific criteria will drive the mixing zone analysis. Idaho has numeric criteria for a variety of pollutants, including toxics (discussed below), temperature, dissolved oxygen, pH, and *E. coli*. Numeric water quality criteria are listed in IDAPA 58.01.02.210 through 02.252. Additionally, IDAPA 58.01.02.401.01 through 401.03 mandates numeric criteria for temperature, turbidity, and total chlorine residual that apply to point source discharges at the edge of the mixing zone unless they are superseded by other more stringent criteria (e.g., in IDAPA 58.01.02.250).

Idaho water quality rules contain two types of numeric aquatic life water quality criteria for the allowable magnitude of toxic substances: acute criteria to protect against acute or lethal effects, and chronic criteria to protect against chronic effects. For individual chemicals, acute criteria were derived from 48- to 96-hour tests of lethality or immobilization. Chronic criteria were derived from long-term (often greater than 28-day) tests that measure effects on growth and reproduction, and in some cases, bioconcentration. The acute criteria should be met at the edge of the acute mixing zone, otherwise known as the zone of initial dilution (ZID), and the chronic criteria should be met at the edge of the chronic mixing zone (IDAPA 58.01.02.060.01.g). (See Figure 1.)

Human health toxics criteria can be divided into carcinogens and non-carcinogens. For carcinogens, an acceptable risk is based on a lifetime incremental cancer risk level of 1 in 100,000 for exposed individuals. For non-carcinogens, an acceptable risk is based on the reference dose (RfD) obtained from EPA's Integrated Risk Information System (IRIS) or other DEQ-approved toxicological data source. The RfD is an estimate of the daily exposure to the human population that is likely to be without appreciable risk of causing deleterious effects during a lifetime. Not all toxic substances have acute, chronic, and human health criteria. Furthermore, some toxic substances do not have any numeric criteria. This void is filled by the narrative toxic substances criterion.

2.2 Effects on Human Health via Domestic Water Supply, Contact Recreation, and Fish Consumption

In making a determination as to whether or not to allow a mixing zone or the best manner in which to monitor a mixing zone, the impacts of that mixing zone on human health must be considered. Depending on the beneficial use of the water body, various human heath-based water quality criteria may be appropriate for use in evaluating and regulating the mixing zone. Potential impacts can be evaluated through water quality criteria associated with ingestion of water (domestic water supply uses) and consumption of fish (recreational uses). In making a determination as to whether human health-based criteria should be considered, the designated use of the water body in question must be known. Information that may be used in determining the appropriate designated beneficial uses is available at http://www.deq.idaho.gov/water/data_reports/surface_water/monitoring/beneficial_uses.cfm.

The following three subsections address water quality criteria developed to protect domestic water supply, contact recreation, and fish consumption.

2.2.1 Domestic Water Supply

Those water bodies designated as Domestic Water Supply (in IDAPA 58.01.02.100.03.a) should have water quality such that they are appropriate for use as drinking water supplies. Thus, the establishment of any mixing zone must not interfere with this beneficial use.

Water quality criteria designed to protect human health for some compounds are more restrictive (i.e., allowable concentrations are lower) than corresponding water quality criteria designed to protect aquatic life. An example of this is arsenic, for which the current human health-based criterion is 50 micrograms per liter (µg/L), while aquatic life-based criteria are 150 µg/L (Criteria Continuous Concentration [CCC]) and 340 µg/L (Criteria Maximum Concentration [CMC]). Another example is the organochlorine pesticide Aldrin, for which the human health-based criterion is 0.000049 µg/L, while the aquatic life-based CMC is 3 µg/L. More information regarding applicable human health-based (and aquatic life-based) water quality criteria is given in IDAPA 58.01.02.210.

A group of compounds that should be viewed with particular caution when included in a potential or existing mixing zone are carcinogens. Carcinogenic pollutants are those known to cause cancer. Often carcinogens are also mutagens and teratogens. A mutagen is a pollutant that causes changes in genetic material (DNA), and a teratogen is a pollutant that causes birth defects. Examples of such compounds include benzene, creosote, lead, and Lindane. These substances are typically related to human health concerns and usually require that humans be exposed to the substances through ingestion of the water or consumption of fish or shellfish exposed to the pollutant.

EPA maintains a list of carcinogenic chemicals at http://www.epa.gov/tri/chemical/oshacarc.htm. Information on evidence of carcinogenic and mutagenic properties of chemicals can be found on EPA's IRIS database (http://www.epa.gov/iris/). A comprehensive source of information on human teratogens is the *Catalog of Teratogenic Agents* (Shepard 2001).

A mixing zone may not be authorized if there is information that reasonably demonstrates that pollutants discharged could be expected to cause carcinogenic, mutagenic, or teratogenic effects on or present a risk to human health. A site-specific analysis of risk may be required for such compounds and, in the absence of such an analysis, the evaluation of any such mixing zone should be based on the most protective assumptions.

When evaluating any proposed mixing zone, its proximity to existing and/or proposed domestic water intakes should be considered. When a mixing zone is granted for pollutants significant to human health, the mixing zone may not overlap a water supply intake. Idaho rules do not specify a minimum safe distance between the end of the mixing zone and the drinking water intake. Dilution models and conservative flow estimates (e.g., harmonic mean flow or 30Q5 [30-day, 5-year minimum statistical flow value]) should be used to determine the potential proximity of the intake and mixing zone. Using these data, best professional judgment should be used in determining whether the mixing zone has the potential to interfere with the domestic water supply beneficial use.

2.2.2 Primary and Secondary Contact Recreation

As discussed previously, most waters in the State of Idaho are presumed to support primary or secondary contact recreation uses. Thus, unless an EPA-approved Use Attainability Analysis removes recreational uses, the establishment of any mixing zone must be protective of these uses.

When considering whether to authorize a mixing zone in an area designated for contact recreational uses, specific information is needed regarding the ability of the public to access the area affected, the spatial extent of the mixing zone, and seasonality of use (e.g., swimming during late summer or whitewater rafting or kayaking during spring high flows). Additional information may be requested from the discharger regarding these uses when evaluating potential impacts of mixing zones.

Of particular concern for discharges from wastewater treatment plants is *E. coli*. Those waters designated for protection of contact recreation are no t to contain *E. coli* in concentrations exceeding a geometric mean of 126 *E. coli* organisms per 100 milliliters (ml) based on a minimum of five samples taken every three to seven days over a 30-day period (IDAPA 58.01.02.251.01.a).

Idaho's water quality standards do not specifically preclude the existence of a mixing zone for *E. coli* in waters designated for primary and secondary contact recreation; however, Idaho rules provide mixing zones should be located so as to not interfere with existing uses. As such, DEQ has not typically authorized mixing zones for bacteria. All available information, including actual recreational use of the receiving water, and best professional judgment should be used in determining whether a mixing zone for *E. coli* is appropriate. For example, if the discharge is adjacent to a public swimming beach, then a mixing zone for *E. coli* is not appropriate. If available data or information with which to make a reasonable decision regarding potential impacts are insufficient, then more information may be required of the discharger.

2.2.3 Fish Consumption

Although fish consumption is not a distinct beneficial use, it is an exposure pathway that is incorporated into the criteria for both domestic water supply and recreational uses. The evaluation of existing or proposed mixing zones to determine potential impacts on harvest and consumption of fish should include a consideration of both the presence in the discharge of substances known to bioaccumulate or otherwise make harvest and consumption of fish less desirable (e.g., organoleptic effects) and the frequency with which fish are harvested in the vicinity of the mixing zone. Thus, the evaluation will include both a consideration of the potential for harm, assuming consumption of fish, and the potential for harvest and consumption of exposed fish.

Although the State of Idaho does not specifically prohibit the allowance of mixing zones for chemicals that bioaccumulate, particular caution should be exercised in allowing such mixing zones, and under some circumstances, they may be denied. The TSD specifically states that:

> *Where fish tissue residues are a concern (either because of measured or predicted residues), mixing zones should not be projected to result in significant health risks to average consumers of fish and shellfish, after considering exposure duration of the affected aquatic organisms in the mixing zone, and the patterns of fisheries use in the area (EPA 1991).*

Restriction or denial of a mixing zone may be considered when the propensity of the contaminant in question has a high potential to bioaccumulate (e.g., a bioconcentration factor [BCF] exceeding 300), the duration of exposure is increased, or the discharge concentration is sufficiently high. The Department will consider "sufficiently high" concentrations to be those that will result in an increase in the downstream water concentration by ten percent or more of either the assimilative capacity or the background concentration, whichever is less. The assimilative capacity is appropriate to use when the background concentration is greater than one-half the criterion. The background concentration is appropriate to use when the background concentration is less than one-half the criterion.

Table 2 presents a list of chemicals that have been identified as significant fish contaminants for human health (EPA 2000c). Generally speaking, lipid soluble (hydrophobic) compounds have a greater potential for bioaccumulation. The chemicals included in Table 2 were selected because of detection in fish monitoring programs, increased persistence in the environment (e.g., half-life exceeding 30 days), high potential for bioaccumulation (e.g., BCF values exceeding 300), and high hazard to human health. The presence of any of these compounds in a mixing zone should be cause for particular concern and scrutiny.

Table 2. Target Analytes Recommended for Fish Sampling Programs[a]

Metals	**Organochlorine Pesticides**
Arsenic (inorganic)	Dicofol
Cadmium	Endosulfan (I and II)
Mercury (methylmercury)	Heptachlor epoxide[c]
Selenium	
Tributyltin (organotin compound)	**Chlorophenoxy Herbicides**
	Oxyfluorfen
PCBs (Polychlorinated biphenyls)	PAHs[d] (Polycyclic aromatic hydrocarbons)
Total PCBs (sum of PCB congeners or Aroclors)[b]	
	Dioxins/Furans[e]

[a] This table has been adapted from the Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol. 2: Risk Assessment and Fish Consumption Limits, 3rd ed. (EPA 2000c).
[b] Analysis of total PCBs (as the sum of Aroclors or PCB congeners) is recommended for conducting human health risk assessments for total PCBs (see EPA 2000d, Sections 4.3.6 and 5.3.2.6). Standard methods known as EPA Method 608 and EPA Method 1668 are available for Aroclor and congener analysis, respectively.
[c] Heptachlor epoxide is not a pesticide but a metabolite of the pesticide heptachlor.
[d] It is recommended that tissue samples be analyzed for benzo[a]pyrene and 14 other PAHs and that the order-of-magnitude relative potencies given for these PAHs be used to calculate a potency equivalency concentration (PEC) for each sample (see EPA 2000d, Section 5).
[e] It is recommended that the seventeen 2,3,7,8-substituted tetra- through octa-chlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) and the 12 dioxin-like PCBs be determined and a toxicity-weighted total concentration be calculated for each sample (Van den Berg et al. 1998). (See EPA 2000d, Sections 4.3.7 and 5.3.2.6).

Although EPA recognizes organophosphate pesticides as target analytes, these compounds are not included in Table 2 because they usually break down rapidly in aquatic environments. In addition, any pesticides that have been banned for sale or use were not included in Table 2. In Idaho, herbicide and pesticide compounds are not typically contained in effluent; however, metals commonly are. In addition to the information presented in this section, the discussion of bioaccumulation presented in Section 2.3.5 and the discussion of carcinogenic compounds in Section 2.2.1 should be consulted in evaluating the potential for various effluent constituents to cause harm.

In addition to water column criteria, fish tissue criteria are being considered for protection of human health. Idaho has adopted a maximum methylmercury concentration in fish tissues of 0.3 mg/kg and developed the *Implementation Guidance for the Idaho Mercury Water Quality Criteria* (DEQ 2005). This criterion should also be used when evaluating mixing zones.

Although not a human health concern, organoleptic (taste and odor) impacts have water quality criteria which have been recommended by EPA. These criteria may be consulted in making a determination as to whether or not compounds in any proposed discharge will interfere with the beneficial uses of the receiving water (e.g., harvest and consumption of fish). These criteria are listed among the National Recommended Water Quality Criteria and are available at www.epa.gov/waterscience/criteria/wqcriteria.html.

When a mixing zone is in an area commonly used for commercial or recreational fishing, greater caution should be exercised in allowing mixing zones for chemicals known to bioaccumulate or otherwise make harvest and consumption of fish less desirable. Specifically, the TSD (EPA 1991) states that "Mixing zones [for bioaccumulative pollutants] should be restricted such that they do not encroach on areas often used for fish harvesting, particularly of stationary species such as shellfish." The discharger may be required to submit information regarding the frequency of such activities or access points for such activities in the vicinity of the mixing zone. Using this and other information, DEQ staff should use best professional judgment in determining whether to allow a mixing zone for the chemical(s) of concern.

2.3 Effects on Aquatic Life, Including Toxicity, Zone of Passage, Spawning, and Bioaccumulation

Mixing zones have the potential to impact aquatic life (i.e., fish, benthic macroinvertebrates, and algae) by adding toxic concentrations of chemicals to the water (e.g., elevated concentrations of metals or raising or lowering pH beyond physiological thresholds) or through physical impacts such as degraded habitat, decreased dissolved oxygen concentrations, increased temperature, or increased sedimentation and/or turbidity. Both physical and chemical impacts to the receiving water can create a barrier to upstream or downstream movement by fish and aquatic macroinvertebrates. (For further discussion, see Section 2.3.1). As a result, mixing zones should be granted on a case-by-case basis, kept as small as possible, and approved only if acutely toxic conditions and barrier to fish passage are avoided.

Evaluation of any existing or proposed mixing zone must take into consideration the following:

- composition of the aquatic community
- seasonal dynamics of the water body (both physical dynamics such as snowmelt runoff and ecological dynamics such as migrating fish)
- physical impacts the discharge may cause
- concentrations and nature of pollutants that may interfere with the designated aquatic life uses of that water body

In general, the risk of any mixing zone to aquatic life increases with the extent of the mixing zone and the magnitude, duration, and frequency of pollutant exposure. It is critical, therefore, to determine the concentration of toxins in the mixing zone as well as all expected physical and chemical habitat changes that would be associated with it. It is also important to evaluate how frequently the aquatic community will be exposed to the discharge, as the more frequent a discharge, the more likely it is to present a risk to aquatic life and beneficial uses.

For more information on biological communities:

State Fisheries Management Plans
http://fishandgame.idaho.gov/cms/fish/programs/fish_plan.pdf (Note that this is a large file, which may download slowly.)

Critical habitat for salmon and steelhead
http://www.nwr.noaa.gov/Publications/FR-Notices/2005/upload/70FR37160.pdf

Bull trout
http://www.fws.gov/pacific/bulltrout/
http://species.idaho.gov/list/bulltrout.html

Biological communities in certain receiving waters (e.g., those which provide habitat for salmonid spawning and/or species of special concern) may be too sensitive to allow a mixing zone at any time because essential habitat would be affected, or vulnerable life stages and/or listed threatened and endangered species are resident within or near the proposed mixing zone. Alternatively, the seasonal sensitivity of an aquatic community (e.g., during spawning runs) may require that mixing zones be shrunk or prohibited during certain periods of the year. (See Section 2.3.3 for more on seasonal issues). In all cases, the biological community should be thoroughly characterized before a mixing zone is permitted to ensure that the biological condition and support of designated beneficial uses can be quantified and monitored prior to initiation of discharge (if possible) and over the life of the permit. Section 4.0 presents a discussion of monitoring and evaluation methods which may be used for community characterization.

Information regarding the aquatic communities expected to be present in different water bodies of Idaho is available in the Idaho Department of Fish and Game's (IDF&G) State Fisheries Management Plans. These plans, as well as lists of species of special concern (e.g., bull trout) and critical habitat designations (see Section 2.3.4), should be consulted early in the mixing zone review process to determine the potential for occurrence of species of special concern. Critical habitat is identified for salmon and steelhead in the Federal Register (2005). Bull trout recovery plans, critical habitat, and other information are available from the U.S. Fish and Wildlife Service (USFWS). Consultation with USFWS (for threatened species such as bull trout) and the National Marine Fisheries Service (NMFS) (for anadromous fish such as chinook salmon) may be required when there is a reasonable chance that species of special concern may occur in the area of the proposed mixing zone.

The designated use of the water body (e.g., salmonid spawning) may be a significant factor in determining the type of biological community present, as well as the acceptability of, or limits for, a given mixing zone. Although the State water quality criteria for toxics do not vary with the designated aquatic life use, some numeric cr
criteria that vary with the designated aquatic
ammonia. Thus, the designated use of the wa
criteria in mixing zones. The designated use
applicable water quality criteria as well as th
evaluation of a given mixing zone.

For more information on toxicity:

ECOTOX databases
http://cfpub.epa.gov/ecotox/

Thompson Creek Mine
http://www.deq.idaho.gov/water/data_reports/surface_water/water_bodies/thompson_creek_mixing_zone_report.pdf

The tolerance of different organisms to the e
stage, and time of year. Prior to authorizing
community, particularly species of special c
should be examined. EPA has a regional list of relative tolerance values for aquatic

macroinvertebrates and fish (EPA 1999). Additional information regarding the chemical tolerances of many species may be found in EPA Ambient Water Quality Criteria Documents, which form the basis for many state water quality standards. These documents are available at http://www.epa.gov/waterscience/criteria/aqlife.html and contain species-specific chemical toxicity data for many species that occur in Idaho or species that may be used as surrogates to evaluate potential harm. Additionally, evidence may be required that demonstrates that the expected concentrations of pollutants are unlikely to have significant impacts on aquatic life.

2.3.1 Toxicity to Aquatic Organisms

IDAPA 58.01.02.210 includes numeric water quality criteria that address the effects of toxic pollutants on aquatic life. Further toxicity data can be found in EPA's ECOTOX databases, scientific literature in general, and in the DEQ evaluation report of proposed mixing zones for the Thompson Creek Mine, which also includes discussions of potential impacts to species of special concern. Using these resources and information provided by the discharger, it must be determined that acutely toxic conditions will not occur within the mixing zone and that all acute and chronic water quality criteria are met at the edge of the proposed ZID and chronic mixing zone, respectively (see Figure 1).

It is possible to allow ZIDs and at the same time ensure no acutely toxic conditions occur. Acute criteria, which are defined as one-half the final acute value for specific toxicants, describe the concentration at which toxic effects (such as lethality) will not occur when the exposure is less than one hour. Acutely toxic conditions are those conditions that cause lethality after short-term exposure (e.g., one hour or less). Acute lethality is generally not expected when an organism drifting through the mixing zone along the path of maximum exposure would not be exposed to concentrations exceeding the acute criteria when averaged over a one-hour period (EPA 1991). It can be assumed that no lethality to passing organisms will occur if at least one of the following is met:

1. The discharge is of high velocity ($\geq$ 3 m/s) and the ZID is less than fifty times the length scale (defined as the square root of the cross-sectional area of the discharge pipe) in any direction; or

2. The acute criterion will be met within 10% of the distance from the edge of the outfall to the edge of the chronic mixing zone (when the acute to chronic ratio is equal to 10 or more); or

3. The acute criterion will be met within a distance of five times the local water depth in any horizontal direction from the outfall; or

4. The discharger provides information showing that a drifting organism, when traveling through the path of maximum exposure, would pass through the acute mixing zone within 15 minutes.

Whole Effluent Toxicity

In addition to evaluating individual toxic constituents, it may be appropriate to examine the aggregate toxicity of an effluent. Because of the complexity of effluents, it is impossible to estimate their final toxicity without directly measuring it through whole effluent toxicity (WET) tests. WET tests account for the toxicity of unknown constituents as well as synergistic or antagonistic effects among the constituents. These laboratory tests involve exposing representative aquatic organisms to various dilutions of effluent under specific conditions. The response of these organisms is used to quantify the toxicity of the aggregate effluent. Various responses, or endpoints, can be used to quantify toxicity, including the lethal concentration in which 50% of the test organisms die (known as lethal concentration fifty, or LC_{50}), the no observed effects concentration (NOEC), and the lowest observed effects concentration (LOEC).

For ease of understanding and use in discharge permits, effluent toxicity is reported in toxic units. A toxic unit (TU) is the reciprocal of the percentage of effluent that causes a specific measured acute or chronic endpoint. Acute toxic units (TU_a) and chronic toxic units (TU_c) can be calculated as follows:

$$TU_a = 100/LC_{50}$$
$$TU_c = 100/NOEC$$

Idaho does not have numeric criteria for WET. Rather, WET tests are used to determine compliance with the narrative criteria for hazardous and toxic substances (IDAPA 58.01.02.200.01 and 200.02, respectively). Typically, EPA interprets Idaho's narrative criterion for toxics to mean a $TU_c = 1$ and $TU_a = 0.3$. This interpretation is consistent with what is recommended in the TSD (EPA 1991). For mixing zones, IDAPA 58.01.02.60.01.h states that concentrations of hazardous materials within the mixing zone should not exceed the 96 hour LC_{50} for biota significant to the receiving water's aquatic community. It is preferable that acute toxicity limits be met at the end of the discharge pipe; however, DEQ may allow acute toxicity limits to be met at the edge of the ZID, so long as lethality does not occur to organisms passing through the ZID. Chronic WET limits should be based on the instream concentration of effluent at the edge of the chronic mixing zone. The most recent EPA WET guidance (EPA 2002b, 2002c) should be followed for all WET testing.

2.3.2 Avoidance Behavior/Zone of Passage

In addition to the physical limitations on the allowable sizes of mixing zones discussed in Section 2.5, the extent of the mixing zone may be restricted in order to ensure sufficient stream area and volume for a zone of passage for fish. Both anadromous (e.g., chinook salmon and steelhead trout) and fluvial species (e.g., bull trout) migrate downstream as juveniles then upstream to spawn as adults. Resident fish may also require adequate zones of passage to maintain the integrity of the water body. Thus, any established mixing zones must provide an adequate zone of passage in order to satisfy the requirement that the mixing zone not interfere with established beneficial uses. The following are of primary concern in evaluating the zone of passage: concentrations of various pollutants that are known to elicit an avoidance behavior, and location of the mixing zone relative to suitable stream velocities and depths for fish passage.

A comprehensive review of the scientific literature on fish avoidance was conducted by DEQ for the Thompson Creek Mine facility. This report, which can be used as a model for evaluation of fish passage issues associated with mixing zones, identified fish avoidance thresholds for cadmium, copper, chromium, nickel, lead, mercury, and zinc (Table 3). Additional pollutants were also discussed in the document, which is available at http://www.deq.idaho.gov/water/data_reports/surface_water/water_bodies/thompson_creek_mixi4ng_zone_report.pdf. Additional avoidance threshold values may be presented by the permit applicant; however, these must be supported by adequate and appropriate scientific literature.

Table 3. Threshold Concentrations (µg/l) Observed to Elicit Avoidance Responses in Salmonids (DEQ 2000)

Selected Avoidance Thresholds	Cadmium	Copper	Chromium	Nickel	Lead	Mercury	Zinc
Lab	8	3	10	24	14	0.2	14
Field	***16***	***3***	***20***	***48***	***28***	***0.4***	***28***

Note: Except for copper, lab avoidance thresholds from the studies reviewed multiplied the lowest lab-to-field response ratio by two in order to obtain field avoidance thresholds. Because of ambiguity with the threshold avoidance response of juvenile chinook salmon to copper, the recommended avoidance threshold is 3 µg/l, without multiplication by the lab-to-field response ratio.

The allowable size of the mixing zone must take into account not only water quality criteria, but also concentrations of various pollutants known to elicit an avoidance response in both the expected resident and migratory fish species. Since fish have been shown to have their upstream passage blocked when encountering elevated concentrations of pollutants, any permitted mixing zone must provide a sufficient zone of fish passage such that the allowable mixing zone does not have the potential to interfere with fish movements.

From a physical perspective, the size limitations as described in Section 2.5 on the extent of a mixing zone are expected to provide an adequate zone of passage. However, in order to ensure that the mixing zone "does not cause unreasonable interference with or danger to existing beneficial uses," (IDAPA 58.01.02.060.a) site-specific considerations of both channel morphology and species of particular concern must be considered. Evaluation of channel morphology could be completed in conjunction with modeling efforts, as these efforts may involve detailed description of the receiving water. Of concern are instances in which a mixing zone is proposed for stream channels which contain a limited percentage of stream width with characteristics capable of supporting fish passage (e.g., depth or flow volume). For example, it is not unusual for limited areas of some streams to contain areas with a well-defined thalweg adjacent to a comparatively large gravel bar over which only shallow, diffuse flow travels. In such situations, a mixing zone could occupy less than 25% of the stream width, or even less than 25% of the stream flow, but close to 100% of the useable area of the stream for fish passage. In such cases, a site-specific determination of the appropriate

Idaho mixing zone rules list 25% stream width and 25% stream volume as principles to consider when defining a mixing zone. This example illustrates that there may be times when mixing zone determinations are driven by more limiting factors.

physical extent of a mixing zone must be made. As indicated, such considerations must take into account requirements of species of concern (e.g., migrating chinook salmon).

2.3.3 Spawning

Of particular concern in Idaho is the protection of the spawning activities of salmonids (trout and salmon). *Oncorhynchus* species spawn by depositing eggs and sperm in a depression cut into the stream bottom of shallow, silt-free riffle/run habitats from large rivers to headwater streams. In general, salmon and trout typically choose to spawn in streams that are shallow, clear, and cold with a strong upwelling of water through the gravel. Discharges containing elevated suspended solids, for example, may clog these critical gravel beds. Sockeye salmon spawning occurs almost exclusively in lakes or streams that connect to lakes. The female sockeye most often selects a redd site in an area of the stream with fine gravels. Detailed descriptions of chinook salmon, steelhead, and bull trout spawning preferences and habitat needs by life stage are provided as part of the Salmon River Idaho restoration project. Information on sockeye habitat requirements can be obtained from the Washington Department of Fish and Wildlife. Any discharge that significantly alters habitat, lowers the dissolved oxygen, or increases the temperature of a water body is likely to impact spawning activities.

For more information on salmon habitat:

Salmon River Restoration Project
www.nww.usace.army.mil/salmonriver/default.htm

Washington Department of Fish and Wildlife – Sockeye Information
www.wdfw.wa.gov/fish/sockeye/ecosystem.htm

In order to be adequately protective of vulnerable fish communities, mixing zones for Idaho's streams and rivers may be prohibited within all areas during all times of the year that the area provides salmonid fish spawning habitat. The spawning periods for salmonids occur in seasonal blocks. During late winter and spring, cutthroat trout, rainbow trout, and steelhead move into spawning habitats. Anadromous and landlocked salmon (coho, chinook, sockeye, and kokanee) spawn during late summer and fall. Brown trout, brook trout, and bull trout will typically spawn in the fall and early winter. In order for a mixing zone to be allowed in any spawning area, the applicant must demonstrate that (1) there will be no adverse impact to spawning salmonids, salmonid eggs, or alevins within the mixing zone when the discharge will occur, and (2) that the discharge will not adversely affect the capability of the area to support ongoing and future spawning, incubation, and rearing activities. Whether or not the mixing zone is to be authorized during fish spawning seasons should be carefully investigated.

The applicant for a mixing zone may be required to provide documentation that the pollutants discharged do not have the potential to interfere with present or future salmonid spawning, incubation, or rearing activities in the vicinity of the proposed mixing zone. Further consultation with NMFS, USFWS, and IDF&G may be necessary to determine potential impacts on spawning areas.

2.3.4 Species of Special Concern

Of particular concern in evaluating potential a
species designated by the State as "species of s
Idaho, low populations, or threats to their exist
fisheries include rainbow trout, cutthroat trout,
kokanee salmon, sockeye salmon, whitefish, a
all of particular ecological, social, and econom

A mixing zone will not be granted if it is likely
threatened species or result in the destruction o
habitat (Federal Register 2001). All mixing zo
analysis of the potential for impacts to habitat used for spawning by endangered or threatened species or species of special concern. Further, in order to be adequately protective of vulnerable fish communities, mixing zones for Idaho's streams and rivers may not be allowed within all areas during any time of the year that the area provides critical habitat for any life stage of sockeye salmon, chinook salmon, steelhead trout, Kootenai River population of white sturgeon, or bull trout.

For more information on bioaccumulation:

Bioaccumulative properties
http://toxics.usgs.gov/definitions/bioaccumulation.html

EPA PBT Chemical Program
http://www.epa.gov/pbt/

Great Lakes
http://www.epa.gov/waterscience/gli/mixingzones/

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) (which was amended by the Sustainable Fisheries Act of 1996), established procedures designed to identify, conserve, and enhance Essential Fish Habitat (EFH) for those species regulated under a Federal fisheries management plan. MSA procedures are also very useful for identifying essential salmon spawning habitat in order to determine the appropriateness of a mixing zone. EFH for the Pacific coast salmon fishery has been defined as those waters and substrates necessary for salmon production, which are needed to support a long-term sustainable salmon fishery while maintaining the contributions of salmon to a healthy ecosystem. Salmon habitat is also protected under the Endangered Species Act (ESA), which requires the federal government to designate "critical habitat" for any species it lists under the ESA. Salmon and steelhead "critical habitat" is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if those areas contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation. For more information on identifying EFH and critical habitat for Pacific salmon and steelhead, see the National Oceanic and Atmospheric Administration's northwest region website at www.nwr.noaa.gov/Salmon-Habitat.

2.3.5 Bioaccumulation

Bioaccumulation is the concentration of substances in an organism or part of an organism from its diet or environment. The process involves sequestration of the substances, which leads to the organism having a higher internal concentration of the substance than its surrounding environment. Though similar to bioaccumulation, bioconcentration involves uptake from water only. In general, substances that have properties that make them more lipid soluble and less soluble in water are more likely to bioaccumulate. A general discussion of these properties is available through the U.S. Geologic Survey (USGS) website (see the first link in the text box below). Well-known bioaccumulative substances include mercury, poly-chlorinated biphenyls

(PCBs), and chlorinated pesticides. More information on and examples of such chemicals can be found at the EPA Persistent, Bioaccumulative, and Toxic (PBT) Chemical Program website, which maintains a list of priority PBT chemicals. Additionally, EPA's Great Lakes Initiative has identified 22 bioaccumulative chemicals of concern (see Table 4) for which mixing zones are not allowed in the Great Lakes.

Table 4. List of 22 Bioaccumulative Chemicals for which Mixing Zones are Prohibited in the Great Lakes

Compound	
Lindane	Mirex
Hexachlorocyclohexane (BHC)	Hexachlorobenezene
alpha-Hexachlorocyclohexane	Chlordane
beta-Hexachlorocyclohexane	DDD[a]
delta-Hexachlorocyclohexane	DDT[b]
Hexachlorobutadiene	DDE[c]
Photomirex	Octachlorostyrene
1,2,4,5-Tetrachlorobenzene	PCBs[d]
Toxaphene	2,3,7,8-TCDD[e]
Pentachlorobenzene	Mercury
1,2,3,4-Tetrachlorobenzene	Dieldrin

Notes: [a]DDD: dichlorodiphenyldichloroethane, [b]DDE: dichlorodiphenyldichloroethylene, [c]DDT: dichlorodiphenyltrichloroethane, [d]PCB: poly-chlorinated biphenyl, [e]2,3,7,8-TCDD: tetrachlorodibenzo-p-dioxin

Idaho does not specifically prohibit mixing zones for compounds that have the potential to bioaccumulate. However, permitting of mixing zones for bioaccumulative compounds should only be done when there is a high degree of certainty that such compounds will not interfere with the beneficial uses in that water body. Thus, mixing zones for bioaccumulative compounds should be restricted or denied unless there is sufficient evidence that allowing a mixing zone for the compound(s) in question will not:

- Exceed the assimilative capacity of the receiving system
- Lead to elevated tissue concentrations in fish and benthic macroinvertebrates or other organisms
- Violate the Idaho water quality standards that require mixing zones to be free from toxic chemicals in toxic amounts, which includes toxicity caused through food-chain transfer

In applying for a mixing zone for bioaccumulative compounds, the discharger may be required to provide information regarding the potential for that compound to bioaccumulate or bioconcentrate in the system in question. In general, the residence time of the compound will increase the propensity to bioaccumulate (e.g., fish occupying a fast-flowing stream are likely less subject to bioaccumulation than those occupying a lake); however, bioaccumulation can occur in all systems, given the right conditions. Information the discharger may be required to provide could include the expected fate and transport of the compound in the system; potential impacts on all species, including species of special concern; and a plan to monitor tissue and sediment or water samples (if determined to be appropriate), both before and after establishment of the mixing zone. It is critical that monitoring of tissue concentrations (and possibly other matrices, such as sediment) be initiated prior to permitting of the mixing zone and be continued through the life of the permit. A final consideration should be for the potential impacts on human health (Section 2.2).

2.4 Required Chemical Analyses

Where possible, all analytical methods used to measure pollutants in the effluent and receiving water body should be approved by EPA. Further, the detection limits and reporting limits should be sufficiently low to ensure that concentrations of concern can actually be reliably measured. Of particular concern are chemicals with very low water quality criteria values such as cadmium. EPA's Office of Science and Technology is a good source for information regarding required methods and their detection limits (http://www.epa.gov/ost/methods/).

2.5 General Size and Location Principles to Consider

Mixing zones should be kept as small as practicable to ensure they do not impact the integrity of the water body as a whole. DEQ's mixing zone policy lists specific principles that should be considered when evaluating the size and location of a mixing zone. However, it is important to note that these principles are not regulatory requirements, and DEQ has discretion to depart from these principles. The following subsections discuss each of the size and location principles in detail.

2.5.1 Flowing Waters

Flow Principle

As described in IDAPA 58.01.02.060.01(e)(iv), a mixing zone should not include more than 25% of the volume of the critical stream flow. Efforts must be made to keep the mixing zone as small as possible. In order to accomplish this, 10% of the critical low flow may be initially considered for dilution; however, additional volume (in 5% increments) can be used if needed (e.g. it is determined the WQBEL can not be practically achieved). When determining whether a WQBEL can be practically achieved, issues such as technological feasibility and cost feasibility may be considered. The rationale for this approach is to ensure that any applicable mixing zone be as small as possible. DEQ may authorize a mixing zone that includes more than 25% of the volume of the critical stream flow provided the discharger demonstrates such dilution is needed and submits sufficient information illustrating that the increased mixing zone size will not unreasonably interfere with the beneficial uses of the receiving water body. Table 5 lists the critical flow values that apply to mixing zones, as described in IDAPA 58.01.02.210.03.

Table 5. Critical Flows to Use in Mixing Zone Evaluations

Criteria	Critical Flow
Aquatic Life – Toxics[1]	
Acute toxic criteria (CMC)[2]	1Q10 or 1B3
Chronic toxic criteria (CCC)[3]	7Q10 or 4B3
Aquatic Life – Non conventionals[4]	
Temperature	7Q10
Ammonia	7Q10
Phosphorus	Seasonal average (May to September)
Human Health – Toxics[1]	
Non-carcinogens	30Q5
Carcinogens	Harmonic mean flow

1Q10: lowest one-day flow with an average recurrence frequency of 10 years
1B3: biologically based low flow which indicates an allowable exceedance of once every 3 years
7Q10: lowest 7-day average flow with an average recurrence frequency of 10 years
4B3: biologically based low flow which indicates an allowable exceedance for 4 consecutive days once every 3 years
30Q5: lowest 30-day average flow with an average recurrence frequency of 5 years
Harmonic mean flow: long-term mean flow value calculated by dividing the number of daily flows by the sum of the reciprocals of those daily flows.

1 These critical flows are specified in IDAPA 58.01.02.210.03.b, and thus are non-negotiable.
2 CMC: Criterion Maximum Concentration.
3 CCC: Criterion Continuous Concentration.
4 These critical flows are not specified in Idaho water quality standards; thus, alternative flows may be used with DEQ approval.

To determine critical flow values where there is an extended record of flow data at or near the discharge point, EPA recommends using the EPA Office of Research and Development's DFLOW program, which can be downloaded free of charge. Alternatively, the USGS SWSTAT can be used. Other statistical methods can be proposed by dischargers, although they should consult with DEQ staff prior to using alternative methods.

Both DFLOW and SWSTAT rely upon the availability of long-term flow data. These models require at least three years, and preferably 10 years, of flow data to provide reliable statistical results. Such data may be independently collected by the discharger or another party within the watershed. Alternatively (as well as to verify discharger data), long-term flow data may be available if there is a nearby USGS stream gage. If there is no suitable USGS flow gage, the approximate size of a river using topozone or other maps can help verify the applicant's flow data/estimates.

In many cases, long-term flow data are not available for a specific receiving water. In that case, one option is to identify comparable watersheds in the area that have long-term data. A simple approach is to then calculate the critical low flows for the comparable watershed and estimate the low flows for the receiving water based on the ratio of upstream drainage areas. Further, long-term flow data can be compiled for multiple, comparable watersheds in the area. These data can be used to develop a correlation between drainage area size and flow, which can then be used to estimate the low flow in the receiving water. Care must be taken in using this approach because of the difficulties in "comparing" watersheds due to potential differences in local precipitation, elevation, topography, soils, aspect, etc.

DEQ will consider other stream flow estimates (of which a proportion can be allocated to the mixing zone) where requested by dischargers. Such requests, however, must be accompanied by supporting information to demonstrate that the mixing zones will not affect the designated uses of the water body. For example, mixing zones could be based on tiered stream flows. Appropriate ranges (tiers) of stream flows can be established that range from very low minimum stream flows such as the 7Q10 (the 7-day, 10-year minimum statistical flow value) to very high normal spring runoff levels. The allowable mixing volume would be based on the lowest level of the range. For example, if DEQ establishes a tier between 100 and 150 cubic feet per second (cfs), then the allowable mixing volume would be based on a proportion of 100 cfs. This approach was used by DEQ, EPA, and the Forest Service in establishing a mixing zone for discharges from the Hecla Mining Company Grouse Creek Mine (http://yosemite.epa.gov/r10/water.nsf/NPDES+Permits/Current+ID1319).

For more information on critical flows:

DFLOW
http://epa.gov/waterscience/dflow/index.htm

SWSTAT Instructions
http://water.usgs.gov/software/swstat.html

USGS Gage Information
http://waterdata.usgs.gov/nwis/sw

Topozone
http://www.topozone.com

Width Principle

The concentration of the constituent(s) being discharged to a mixing zone should meet or be less than the applicable chronic criteria before the width of the effluent plume becomes wider than 25% of the total width of the stream (IDAPA 58.01.02.060.01.e.ii). In addition, the cumulative width of adjacent mixing zones should not exceed 50% of the total width of the receiving water (IDAPA 58.01.02.060.01.e.i). The relevant width of the stream is the wetted width of the water flowing in the channel. Wetted width is a dynamic parameter that varies with flow. Additionally, at any given stream flow, channel widths and wetted widths also naturally change as one goes upstream or downstream. As channel gradients become steeper, flow often becomes more constricted and velocities increase. Likewise, channels tend to spread out and widen with decreasing gradients and lower flow velocities.

It is important, therefore, to define the flow regime (i.e., the level of water) and the channel cross-section downstream where constituent concentrations meet the chronic criteria. Mixing zone models, such as CORMIX, can be used as tools to compare different levels of flow, the width and length of the effluent plume, and the appropriate cross-section where the critical wetted width would be established as a compliance point. Since aquatic life toxics criteria are typically considered during analyses, DEQ generally uses the 7Q10 to define the critical wetted-width and the location of the compliance cross-section. This use of the 7Q10 is also consistent with the flow volume approach discussed above. In most cases, determining the mixing zone width at the 7Q10 would ensure that the mixing of effluent plumes would result in meeting chronic criteria prior to becoming wider than 25% of the stream width at all flow conditions. However, there may be instances where as stream flow and velocity increase, effluent plumes travel greater distances before becoming sufficiently mixed to meet criteria. In addition, wider plumes could be observed at higher flows in some instances. Where the required mixing zone to meet chronic criteria approaches 25% of the stream, additional studies and modeling may be necessary to predict the length, width, and amount of mixing at higher flow conditions.

Distance to Shoreline Principle

The concentration of the constituent(s) being discharged to a mixing zone should meet or be less than the applicable chronic criteria before the edge of the effluent plume is closer to the 7Q10 shoreline than 15% of that stream width (IDAPA 58.01.02.060.01.e.iii). For these purposes, 15% of the stream width is defined as 15% of the wetted width of the water flowing in the channel when the stream flow is at the 7Q10 level.

To provide an example, assume that the wetted width of the 7Q10 low-flow is 40 feet. Fifteen percent of 40 feet is 6 feet. In this case, the concentration of the constituent(s) being discharged to a mixing zone must meet or be less than the applicable chronic criteria before the edge of the effluent plume comes closer than 6 feet to the location of the 7Q10 low-flow shoreline. The 6 foot criterion would apply for all flow levels.

As discussed for the 25% width criterion, at any given stream flow, channel widths and wetted widths also naturally change as one goes upstream or downstream. Open channel hydraulics models such as the Hydrologic Engineering Centers River Analysis System (HEC-RAS) could be used to define the wetted width and shoreline of the 7Q10 low-flow. Mixing zone models such as CORMIX can be used to compare different levels of flow and the width and length of the effluent plume; they can also define the appropriate cross-section where the critical wetted width would be established as a compliance point.

The distance to shoreline principle can be interpreted as prohibiting shore-hugging plumes, which supports EPA's position (1994) that shore-hugging plumes should be avoided. However, although DEQ believes that these principles should be followed to the maximum extent practicable, these principles are not binding. Outfalls constructed at the bank generally result in shore-hugging plumes. Currently, most dischargers in Idaho have outfall structures located on the bank, perpendicular to stream flow. DEQ encourages, but does not require, diffusers. While DEQ recognizes there may be instances where installation of a diffuser results in more harm than good, or does not result in any added environmental benefits, diffusers generally result in more rapid mixing, decrease the area containing elevated concentrations, and thus minimize biological effects.

2.5.2 Lakes and Reservoirs

IDAPA 58.01.02.060.01.f.i limits the size of mixing zones to 10% of the lake's surface area. Wherever practicable, the discharger should provide an estimate of the maximum area of the lake's surface. The size of the lake may be estimated based on USGS topographic maps and/or other maps that delineate the lake boundaries. IDAPA 58.01.02.060.01.f.ii provides that adjacent mixing zones (from different discharge points) should be no closer than the greatest horizontal dimension of any of the individual zones. This is demonstrated by overlaying the modeled mixing zone dimensions with the overall lake area.

2.5.3 Multiple Mixing Zones

IDAPA 58.01.02.060.01(d) provides that multiple mixing zones can be established for a single discharge, each being specific for one or more pollutants. In addition, a single discharger may be allowed two or more discharge points; however, the sum of the mixing zones from those discharge points should not exceed the area and volume that would be allowed for a single mixing zone (IDAPA 58.01.02.060.01(c)). The mixing zone area and volume are generally determined through modeling, as discussed in Section 6.

2.6 Requirements for Submerged Discharges

IDAPA 58.01.02.060.01(a) indicates that mixing zones may receive discharges from a submerged conduit, pipe, or diffuser. Although not required in Idaho rules, a submerged discharge point is preferable because it enhances hydrodynamic mixing. A description of the discharge location and depth should be provided by the mixing zone applicant.

2.7 Special Resource Waters and Outstanding Resource Waters

Idaho's water quality standards define Outstanding Resource Waters (ORWs) as high quality waters which have been designated by the legislature, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance. An ORW constitutes an outstanding national or state resource that requires protection from point and nonpoint source activities that may lower water quality. A Special Resource Water (SRW) is a segment or water body which is recognized as needing special protection to preserve outstanding or unique characteristics or to maintain current beneficial use.

Mixing zones are not prohibited in SRWs or ORWs, and the same considerations given to proposed mixing zones in other bodies of water should be given to SRWs as well as ORWs. However, the expectations of conditions at the edge of the mixing zone boundary as well as the level of scrutiny given to discharges to either type of waters (ORW or SRW) may be much greater in order to meet the requirements set forth in Idaho's antidegradation policies (IDAPA 58.01.02.051) and rules governing point source discharges to special resource waters (IDAPA 58.01.02.400). Implementation of these provisions is beyond the scope and intent of this manual. However, DEQ's evaluation report of proposed mixing zones for the Thompson Creek Mine (DEQ 2000) provides an excellent example of the type of analysis that may be required for new or increased discharges to SRWs.

2.8 Other Considerations

2.8.1 Assimilative Capacity

Mixing zones can only be granted when there is assimilative capacity in the receiving water body. Generally, mixing zones cannot be granted for parameters for which a water body is considered "impaired;" however, exceptions may be granted for parameters that are non-conservative in nature or when the discharge is considered de minimis.

De minimis discharges are those that will have insignificant (e.g., immeasurable) impacts on the receiving water based on concentration or loading. For example, a wastewater treatment plant discharging heated effluent which does not raise background stream temperatures by more than 0.3ºC at the edge of the applicable mixing zone may be considered a de minimis discharge. De minimis determinations will require a case-by-case evaluation by DEQ and EPA, and in all instances, efforts must be made to ensure the mixing zone is as small as possible and does not unreasonably interfere with the beneficial uses of the water body.

2.8.2 Temperature

When evaluating thermal plumes, DEQ will consider the limitations EPA expressed in *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (2003). Thermal plumes should not cause instantaneous lethality; thermal shock; migration blockage; adverse impacts to spawning, egg incubation, and fry emergence areas; or the loss of cold water refugia. In order to minimize or avoid these types of impacts, the following considerations (EPA 2003) will be taken into account when conducting a mixing zone analysis:

- Within two seconds of plume travel from the point of discharge, maximum temperatures should not exceed 32ºC; and
- The cross-sectional area of the receiving water body exceeding 25ºC should be limited to less than 5%; and
- The cross-sectional area of the receiving water body exceeding 21ºC should be limited to less than 25%, or if upstream temperatures exceed 21ºC, then at least 75% of the receiving water body should not have temperature increases of more than 0.3ºC; and
- In spawning and egg incubation areas, the stream temperatures should not exceed 13ºC, or the temperatures should not be increased by more than 0.3ºC above ambient stream temperatures.

2.8.3 Nonpoint Sources

Mixing zones for nonpoint source activities are not specifically mentioned in Idaho’s water quality standards. However, there are instances where mixing allowances are appropriate for nonpoint source activities (such as large soil absorption systems, underground injection, or septic systems). Determining the allowable area for mixing between discharges from these activities and ambient waters is beyond the scope of this document, as the models presented in Section 6 are designed for point source discharges (such as a pipe or channel).

2.8.4 Effluent-dominated waters

In some cases, the volume of discharge may provide a benefit (e.g. flow augmentation) to the beneficial uses of the receiving water body, and this benefit would be lost if the discharge were to cease. In these instances, DEQ may authorize mixing zones which utilize more than 25% of the stream volume at critical flow as long as the mixing zone does not unreasonably interfere with the beneficial uses of the receiving water body.

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3.0 MIXING ZONE APPROVAL PROCESS

3.1 When are Mixing Zones Considered?

Most commonly, mixing zone determinations are made during the issuance of new NPDES permits or re-issuance of permits with new or potentially modified mixing zones. As discussed in Section 1.3, Idaho has not been delegated NPDES permitting authority; therefore, EPA Region 10 issues NPDES permits for discharges in the State. As part of the permit preparation process, EPA requests a certification under CWA Section 401 that there is reasonable assurance the permit will comply with the State's water quality standards. This certification includes authorization of any proposed mixing zone. In addition, because NPDES permit issuance and reissuance in Idaho is a federal action, EPA must ensure compliance with the ESA, subject to review by the USFWS and NMFS.

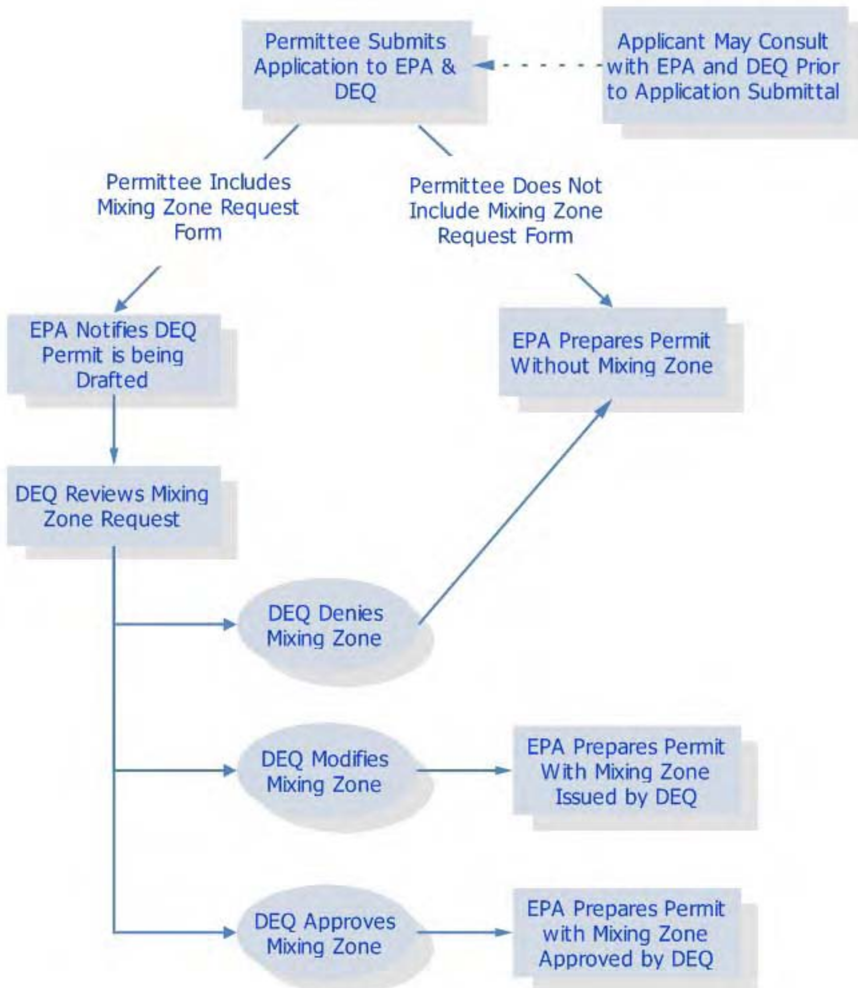
An applicant for an NPDES permit may request a mixing zone as part of the permit application process by completing a mixing zone request form. (See Appendix B. The form will also be available online when this manual is finalized). DEQ staff will review data and other information submitted by the applicant and deny, modify, or approve the mixing zone request. Once established, EPA uses the dilution factor(s) and the projected effluent characteristics to determine if the discharge has a reasonable potential to cause or contribute to excursions above the applicable water quality criteria at the edge of the mixing zone. If necessary, the dilution factors will be used to calculate WQBELs. If the applicant does not request a mixing zone, then it is likely that no dilution will be included in the RPA, and when necessary, subsequent development of WQBELs.

In part, this technical procedures manual is intended to facilitate greater upfront involvement by DEQ staff, working with EPA, in mixing zone evaluations. Section 3.2 describes the process for authorizing mixing zones in new permits, while Section 3.3 addresses the procedures for reissued permits.

3.2 Procedures for New Permits

The proposed process for new permit development is shown in Figure 2. Applicants interested in requesting a mixing zone may complete a mixing zone request form and submit it, along with copies of applications to discharge, to EPA and the appropriate DEQ regional office. If an applicant does not request a mixing zone or does not provide adequate information to determine an appropriate mixing zone, then effluent limitations are likely to be developed to meet criteria at end-of-pipe. Given the current permit backlog, DEQ will not begin to evaluate the mixing zone request until informed by EPA that the NPDES permit is being drafted. Submission of a mixing zone request form will ensure that DEQ is involved early in the permit development process and that the procedures outlined in this document are followed.

Figure 2. Mixing Zone Process for New Permit Applications

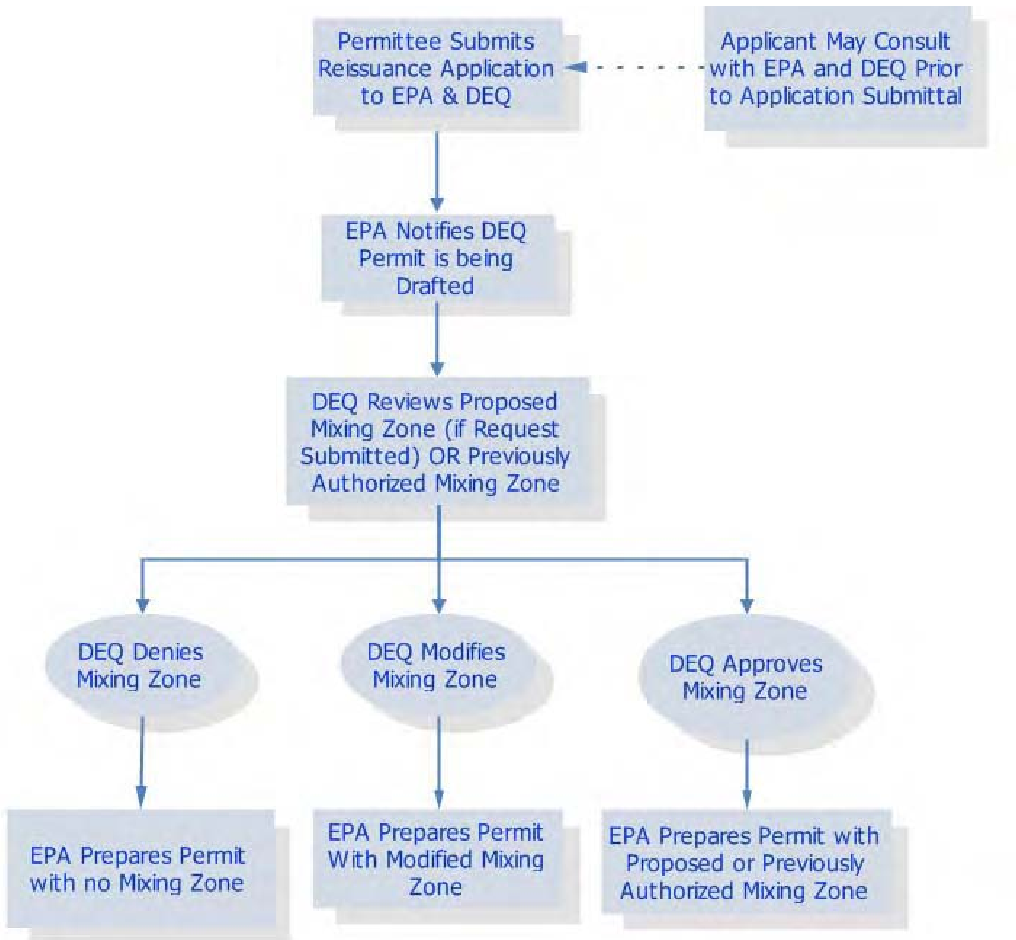


The applicant is responsible for gathering sufficient data, conducting the appropriate analysis, and providing results to DEQ for review. DEQ may assist the applicant with this effort if resources allow. DEQ staff will review the mixing zone request form provided by the applicant and evaluate whether the conclusions are appropriate. In addition, DEQ staff will provide input to the EPA NPDES permit writer on specific monitoring requirements to include in the new permit to verify the mixing zone calculations and ensure that the mixing zone is not having adverse effects on the aquatic environment. DEQ encourages dischargers that are planning to request a mixing zone to meet with both DEQ and EPA prior to application submittal to discuss data collection and analysis requirements.

3.3 Procedures for Reissued Permits

The procedures described below are intended to facilitate greater coordination between EPA and DEQ in reissuing permits with mixing zones. The proposed process for reissuing permits is summarized in Figure 3.

Figure 3. Mixing Zone Process for Reissued Permits



Specifically, DEQ is proposing that EPA share all reissuance applications with DEQ where a mixing zone has previously been granted. If the facility would like to request a new mixing zone, or would like to expand the existing mixing zone, a mixing zone request form should be completed and submitted to EPA and DEQ. Where EPA proposes to re-issue an NPDES permit with an existing mixing zone, DEQ should conduct a review of the original mixing zone determination. In practice, mixing zones are generally not expected to be changed at permit reissuance (unless the applicant requests a change). There are several exceptions, however, including:

- New mixing zone calculations may be needed to address expected changes in effluent limitations, which could arise from revisions to water quality criteria, additional data regarding effluent and/or background water quality, and more information about receiving water hydrodynamics and/or effluent flow. More broadly, as discussed in Section 1.2, mixing zone analysis is not an exact science. Modeling is typically based on a series of assumptions that are often tested and refined through the collection of water body specific data.

- DEQ should consider recent effluent monitoring data to determine whether the existing mixing zone is as small as possible. Specifically, EPA and DEQ should determine whether treatment system performance suggests that a smaller mixing zone could be used. In making such a determination based on technology performance, the preferred approach is to statistically evaluate performance data provided by the discharger.
- For mixing zones based on aquatic life criteria, DEQ should consider any biological data collected for the mixing zone to verify that there are no adverse impacts on aquatic life outside the mixing zone. DEQ may work closely with the IDF&G, USFWS, or NMFS to make such determinations.

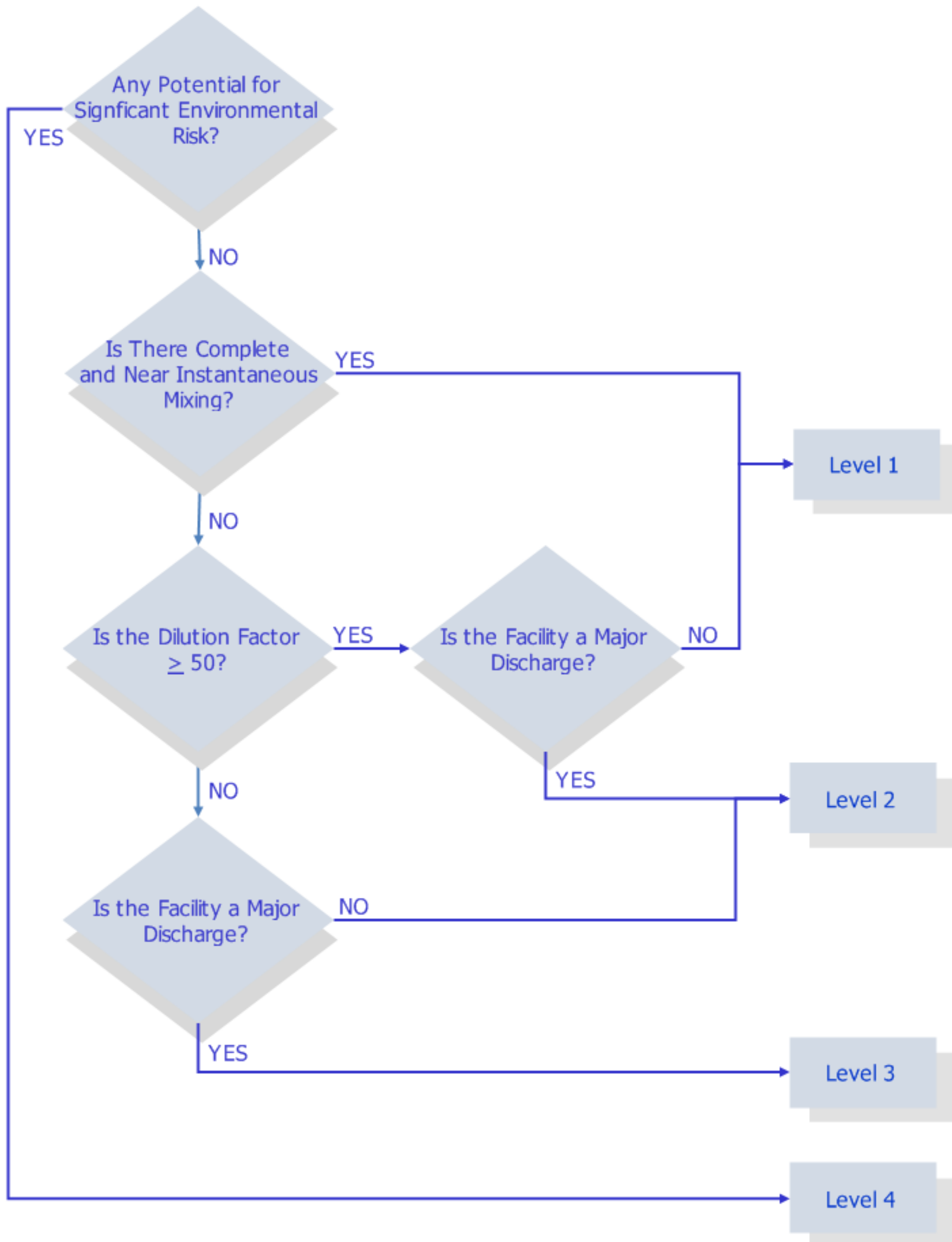
3.4 Mixing Zone Analysis Level of Effort

Not all discharges require an extensive mixing zone analysis to evaluate the potential for chemical, physical, and biological impacts. Furthermore, not all discharges require modeling to depict the size, configuration, and location of the mixing zone. Rather, DEQ believes that the intent of Idaho’s mixing zone policy can be met through various levels of effort. The level of effort needed will depend on the nature of the discharge and the characteristics of the receiving water. These conditions are described in further detail in Section 3.4.7. DEQ has identified four levels of possible effort involved in mixing zone analysis:

- Level 1 – Mass-balance
- Level 2 – Simple
- Level 3 – Moderate
- Level 4 – Complex

Figure 4 depicts the process for determining the appropriate level of analysis. The data requirements for each level of analysis are presented in Appendix C.

Figure 4. Decision Flow Chart for Determining Level of Analysis



3.4.1 Level 1 – Mass balance

The mass balance approach represents the simplest form of calculating an appropriate dilution factor for use in the RPA and WQBEL calculations. This level of analysis is appropriate when the following conditions are met:

- There is no potential for significant environmental risk; and
- There is complete and near instantaneous mixing; or
- The discharger is considered minor, and the dilution factor is greater than 50.

There are limited data needs for this analysis, and no modeling is required. In most situations, pre-discharge biological data will not be required, and although ambient water quality data is desirable, it may not be required.

3.4.2 Level 2 – Simple

The simple mixing zone analysis may be used when there is a low level of risk to the public and aquatic environment. This level of analysis is appropriate when the following conditions are met:

- There is no potential for significant environmental risk; and
- The dilution ratio is greater than 50, and the discharger is considered major; or
- The dilution ratio is less than 50, and the discharger is considered minor.

Although more extensive than the Level 1 analysis, this level of analysis has relatively minimal data needs. Some modeling is required in order to understand the location and configuration of the mixing zone. Many of the modeling inputs can be estimated rather than measured. Similar to level 1, pre-discharge biological data and ambient water quality data may not be required.

3.4.5 Level 3 – Moderate

This level of analysis is appropriate when there is a moderate level of risk to the public and aquatic environment. This level of analysis is appropriate when the following conditions are met:

- There is no potential for significant environmental risk; and
- The dilution ratio is less than 50, and the discharger is considered major.

This level of analysis may require more of the model inputs to be measured rather than estimated. Some flexibility does exist, depending on the situation and reliability of estimates. Pre-discharge biological and chemical data for the receiving stream will likely be required prior to authorization of a mixing zone.

3.4.6 Level 4 – Complex

This level of analysis is appropriate when the potential exists for significant environmental risk to the environment. A level 4 analysis requires a high degree of effort, as most of the model inputs must be measured. In addition, pre-discharge biological and chemical data will be evaluated.

3.4.7 Considerations for Determining Level of Effort

Significant Environmental Risk

There may be situations where a discharge has the potential for significant environmental risk. Such situations may include, but are not limited to:

1. Discharges to areas used for spawning,
2. Discharges containing pollutants significant to human health with the potential to impinge on a drinking water intake,
3. Discharges near areas heavily used for contact recreation purposes,
4. Discharges to areas supporting endangered or threatened species or their habitat, or
5. Discharges of priority persistent bioaccumulatives

These situations necessitate a detailed mixing zone analysis.

Dilution Factor

A dilution factor represents the ratio of a proportion of the receiving water body critical flow and the effluent discharge:

$$\text{Dilution Factor} = \frac{Qs \times P}{Qe}$$

Where: Q_s = critical stream flow (cfs)
P = Proportion (as determined according to the “Flow Principle” discussion in Section 2.5.1)
Q_e = discharge flow (cfs)

If the dilution factor is equal to or greater than 50, a detailed mixing zone analysis may not be required, and the appropriate percentage of the critical flow may be automatically used in the permitting process.

Type of Facility

EPA classifies facilities into two general categories: major or minor. Facility design flow is the primary consideration in this classification scheme for publically owned treatment works (POTWs). If a facilities design flow is greater than or equal to one million gallons per day, then EPA classifies the POTW as major. Industrial facilities are classified as major or minor based upon a scoring system that considers a variety of factors including: standard industrial classification (SIC) code , dilution, type of effluent constituents (e.g. toxics), and available dilution.

If EPA determines the facility is a minor discharger, then a detailed mixing zone analysis may not be required.

Complete and Near Instantaneous Mixing

If the applicant can demonstrate that complete and near instantaneous mixing will occur, then a mixing zone analysis may not be necessary. Situations where complete and near instantaneous mixing may occur include:

1. A multiport diffuser with high velocity discharge (e.g. 3 m/s) that covers up to 25% of the stream width at critical flow.

2. Mean daily effluent discharge that exceeds the critical flow of the receiving water body (effluent-dominated).

3. Concentrations of pollutants that do not vary by more than 5% across the stream width within a downstream distance of not more than one bankfull width.

In such situations, it is reasonable that the permit writer calculate the dilution factor following the procedures previously outlined (Sections 2.5.1, Flow Principle and 3.4.7, Dilution Factor). If requesting more than 25% of the critical low flow, the applicant must provide documentation demonstrating that such increased dilution volumes will not impact the beneficial uses of the receiving water body. This may be in the form of a mixing zone analysis. If complete and near instantaneous mixing does not occur, DEQ may require the permittee to conduct a mixing zone analysis for subsequent DEQ review and approval.

There may be some instances where a complete and near instantaneous mixing situation will require a mixing zone analysis. This will occur if there is reason to believe the discharge has the potential to unreasonably interfere with beneficial uses. An example would be when discharge from a diffuser across 25% of the critical stream width results in a migration barrier to aquatic life.

3.5 Mixing Zone Review and Approval

When mixing zones are proposed, EPA and DEQ will work together during NPDES permit issuance. During the initial application evaluation, DEQ staff should review each discharger’s application for completeness, including specific requests for mixing zones and data supporting mixing zone determinations. DEQ staff should notify the discharger of any additional data needs to complete the permitting process. After the application is determined to be complete, DEQ staff should verify the mixing zone calculations provided by the discharger. After the mixing zone has been verified or calculated, EPA staff will apply the appropriate dilution factor(s) to conduct an RPA and, if necessary, calculate WQBELs. As part of this process, EPA and DEQ may coordinate with the IDF&G, USFWS, and/or NMFS to ensure protection of species of concern. The fact sheet and water quality certification will include DEQ’s mixing zone decision. At a minimum, the fact sheet and water quality certification should include either:

A fact sheet is a document prepared by EPA that accompanies a NPDES permit. The fact sheet summarizes the principle facts and issues (scientific, policy, methodological, and legal) considered in preparing the draft permit. A water quality certification is a decision by the state of Idaho that there is reasonable assurance the permit complies with all applicable requirements of the CWA and State water quality standards.

- The dilution factor used in a Level 1 analysis, or
- The dilution factor used; the size, configuration, and location of the mixing zone; and, where appropriate, calculations showing an analysis regarding the size considerations in IDAPA 58.01.02.060.01.e when a Level 2, 3, or 4 analysis is conducted. A three-dimensional representation overlaying the mixing zone with the receiving water may also be provided. Multiple mixing zones and zones of initial dilution should be displayed, where appropriate.

If EPA determines the discharge could affect ESA-listed species, EPA will prepare and submit a biological assessment/biological evaluation (BA/BE) to USFWS and/or NMFS concurrently with the issuance of the draft NPDES permit. The purpose of the BA/BE is to document the potential effects of the permit action, including mixing zones and WQBELs. Based on the BA/BE, USFWS and/or NMFS may request changes to the permit to ensure protection of threatened and endangered species. As necessary, EPA will also prepare an EFH assessment for submittal to NMFS where EFH could be impacted by the mixing zone.

The public will have an opportunity to comment on the authorized mixing zone during the public comment period(s) for the draft NPDES permit and draft water quality certification. DEQ will work with EPA to address comments related to the authorized mixing zone(s) prior to issuing the final water quality certification.

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4.0 MONITORING

DEQ may require ambient water quality monitoring to evaluate compliance with water quality standards when mixing zones have been approved for discharges. Such monitoring may include assessment of the biological community (both benthic macroinvertebrates and fish), physical habitat, and concentrations of pollutants in sediment, water, and biota found in the receiving stream. An example of detailed monitoring requirements and guidance for mixing zones can be found in the study conducted by DEQ to evaluate the effects on aquatic life of, and to establish conditions for, ongoing discharges and a proposed new mixing zone from the Thompson Creek Mine in Custer County, Idaho (DEQ 2000).

Development of a sampling plan may be required for the monitoring of permitted mixing zones. The plan should detail the characterization of pre-discharge baseline conditions and the post-discharge monitoring program. The level of sampling rigor required to characterize pre-discharge and post-discharge conditions will vary depending on the characteristics of the discharge (a mixing zone for a toxic or bioaccumulative substance would require more monitoring than a substance with a low potential for toxic effects) and the receiving water body (e.g., SRWs, presence of ESA-listed species). The details of the chemical, biological, and physical monitoring and the expected level of sampling rigor that may be required for mixing zones are summarized in the following sections.

4.1 Pollutant Monitoring

During pre-discharge operating conditions, all pollutants expected to be contained in the discharge should be sampled at least quarterly at a monitoring station above the proposed mixing zone for a minimum of one year. However, DEQ may require additional sampling if the results do not appear to be representative of “average” conditions (e.g., sampling was conducted during extreme hydrologic conditions). Single grab samples may be sufficient at this phase of sampling (DEQ 2000). The results of this sampling will be used to characterize background concentrations and seasonal variability.

In some cases, adequate background data may not be available. In these situations, it may be acceptable to assume a background concentration of zero in the mixing zone evaluation. However, DEQ may require upstream monitoring during the first two years of the permit cycle to adequately characterize the background conditions of the receiving water for selected pollutants. This information would be used to evaluate the mixing zone during permit renewal.

During post-discharge operating conditions, DEQ may require the continuation of quarterly upstream monitoring or may increase the sampling frequency to once per month. In addition, DEQ may require the discharger to evaluate whether the discharge is resulting in a violation of water quality standards at the edge of the mixing zone. This may entail quarterly pollutant monitoring at the edge of the mixing zone for a minimum of one year. It is especially important to evaluate whether there are any adverse impacts to water quality when the receiving water body is designated an SRW, and the facility is new or has increased its discharge above the design capacity from that which was previously permitted. Such an evaluation for SRWs is outside the scope of this manual.

In cases where the discharge contains bioaccumulative substances, DEQ believes it prudent to evaluate and/or monitor the sediments in the vicinity of a mixing zone. For instance, the potential for some compounds to bioaccumulate (e.g., selenium) is related to the organic content (e.g., total organic carbon) of the sediments. When required, sediments should be collected using methods such as those outlined by the USGS (e.g., USGS 1994, available at http://ca.water.usgs.gov/pnsp/pest.rep/bs-t.html). This monitoring is particularly important once discharge begins.

4.2 Biological Monitoring

Field bioassessments of instream biota (benthic macroinvertebrate, fish, and periphyton assemblages) are necessary to monitor for the protection of aquatic life beneficial uses. The recommended biological monitoring program for mixing zones is based upon the analyses for the Thompson Creek Mine (DEQ 2000) and a well-established State-wide bioassessment program (Grafe 2002a, 2002b; Grafe et al. 2002, all available at www.deq.idaho.gov/water/data_reports/surface_water/monitoring/publications.cfm). Biological assemblages are valuable monitoring tools because they integrate water quality impacts over longer periods of time than discrete water samples, which only reflect a snapshot of water quality conditions at the time of collection. The recommended approach for evaluating a mixing zone is based upon the collective information provided by chemical data, WET testing, and field bioassessment surveys (Grafe 2002a, 2002b).

Prior to authorizing a mixing zone, an appraisal of the biological conditions as they relate to the proposed mixing zone may be required. The level of effort and detail needed in such an evaluation will vary with the type of discharge, expected dilution, habitat type, etc. (See the discussion in section 4.3 for guidance on when to require more thorough monitoring). For water bodies that have long-term trend biomonitoring data available, the pre-discharge condition (i.e., baseline conditions) can be estimated based on existing data, if the data quality meets Idaho standards (Grafe et al. 2002). However, if no previous program or data exist, or if the data is of insufficient quality, a pre-discharge assessment sampling plan may be required for a proposed mixing zone. In some situations, a mixing zone may be authorized with little or no pre-discharge assessment data; however, DEQ may require a reasonable monitoring program in the discharge permit. In developing and conducting all pre-discharge evaluations, the discharger is expected to collaborate with DEQ. All such sampling should be conducted during base flow conditions, which generally occur from July through September.

4.2.1 Periphyton Monitoring

Benthic algal assemblages, as attached primary producers, are affected by the physical, chemical, and biological conditions present during the period the assemblage developed. Diatoms are particularly useful ecological indicators because they are found in abundance in most lotic systems, can be identified to species by experienced algologists, and are diverse enough to provide multiple indicators of various types of environmental disturbance. The EPA rapid bioassessment protocol (EPA 1999, available at www.epa.gov/owowwtr1/monitoring/rbp/index.html) provides a list of known generalized ecological tolerance values for many species, with extensive references for using periphyton as biological indicators. The protocol also includes methods for sampling, calculating, and interpreting periphyton assemblage data for bioassessment purposes. An Idaho specific diatom index (the river diatom index, or RDI) was developed by Fore and Grafe (2002) and should be used for rivers. An Idaho specific diatom index (the Stream Diatom Index, or SDI) was developed by Cao and others (in press) and should be used for streams. The details of the development of the Idaho RDI, SDI, and the interpretation of diatom assemblage data can be found in Grafe (2002b), Cao et al. (in press), and Bahls (1993).

Primary producers are often very sensitive to pollutants in effluent discharges. Analyses of stressor-specific metrics for mixing zone constituents within the discharge, when possible, will be helpful for assessing the impacts of the mixing zone and establishing causation of any detected degradation. Changes in algal assemblages have been shown to result from metals stress, increased salinity, excess nutrients, decreased dissolved oxygen, changes in pH, and sediment load (DEQ 2000, LaPoint and Waller 2000, Fore and Grafe 2002). The RDI and other applicable diatom metrics and indexes may be used to supplement the invertebrate and fish community assessments that are routinely done in Idaho stream bioassessments, since each assemblage will provide added and unique information on the mechanisms of degradation from a mixing zone (EPA 1999).

The periphyton assemblage should be sampled once annually during base flow conditions. For systems for which there are no or few periphyton data, biannual sampling should be considered, especially during the pre-discharge, baseline phase of sampling. Methods used for periphyton assemblage sampling should follow the methods used by Fore and Grafe (2002). Baseline periphyton assemblage characteristics should be sampled from a minimum of three sites upstream of the proposed mixing zone, from one site within the proposed mixing zone area (if practicable), and from a minimum of three sites downstream from the mixing zone. The timing of post-discharge sampling should be similar to the pre-discharge sampling regime and should begin the first year of discharge. The discharger must show that pre- and post-discharge conditions are similar and that the discharge is not causing unreasonable interference with the beneficial uses before applying for reductions in post-discharge monitoring. The site within the mixing zone, for which there will be at least two consecutive years of monitoring data available, should be used to corroborate or refute impacts to the periphyton assemblage attributed to the mixing zone, if downstream degradation is detected.

4.2.2 Macroinvertebrate Monitoring

Benthic macroinvertebrates have become the most commonly sampled assemblage for bioassessment programs (EPA 1999). Macroinvertebrates are excellent ecological indicators because (1) indigenous benthic macroinvertebrates are ecologically important as an intermediate trophic level between microorganisms and fish; (2) they are abundant in most streams; (3) they have either limited migration patterns or are sessile, which makes them suitable for detecting site-specific impacts; and (4) their life spans are of several months to a few years, which allow them to integrate the impacts of sediment and water quality over time (DEQ 2000). Impacts to the macroinvertebrate assemblage can have large ramifications for other aquatic assemblages because they are an essential component for energy cycling in aquatic ecosystems and are the primary food source for fish, including salmonids and sculpins. Idaho, which has a long history of using benthic macroinvertebrates in the biological assessment of the State’s streams and rivers, has developed a regionally calibrated multimetric index using benthic macroinvertebrates

(Grafe 2002a, 2002b; Jessup and Gerritsen 2002). The sampling methods, laboratory processing, metric selection, data analyses, data interpretation, and quality assurance/quality control (QA/QC) used in mixing zone monitoring programs should comply with these State methods.

Macroinvertebrate community structure analyses have been shown to be reliable and sensitive indicators of adverse environmental impacts from metals, excess nutrients, riparian disturbance, thermal alterations, low dissolved oxygen, pH, sedimentation, and many other stressors (EPA 1999, Yuan and Norton 2003). For example, increased metals concentrations have been associated with declines in the abundance of mayflies, reduced number of different mayfly species, reduced overall numbers of species, and increased dominance by midges, true flies, and worms (DEQ 2000). In fact, declines in mayfly abundance and taxa richness have consistently been reported as sensitive and reliable indicators of metals pollution, especially for copper and zinc (Winner et al. 1980, Clements and Kiffney 1994, Carlisle and Clements 1999, Richardson and Kiffney 2000, Mebane 2001). As stated above for periphyton, analyses of stressor-specific metrics for mixing zone constituents should be conducted, when possible, as they likely will be valuable for characterizing the impacts of the mixing zone and establishing the causation of degradation.

Sampling for macroinvertebrates should be conducted at the same time and within the same sites as the periphyton assemblage. Pre-discharge sampling should be conducted at least once annually during base flow conditions. For systems containing species of special concern or otherwise requiring additional scrutiny (e.g., ORWs), biannual sampling should be considered. Depending on the water body size, the methods described in Grafe (2002a, 2002b) should be followed. Baseline benthic macroinvertebrate assemblage characteristics should be sampled from a minimum of three sites upstream of the proposed mixing zone, from one site within the proposed mixing zone area, and from a minimum of three sites downstream from the expected zone of influence of the mixing zone. After the mixing zone has been established, post-discharge sampling of benthic macoinvertebrates should be conducted during the same period(s) and at the same locations as the pre-discharge sampling regime. The discharger must show that pre- and post-discharge conditions are similar and that the discharge is not causing unreasonable interference with the beneficial uses before applying for reductions in post-discharge monitoring. The site within the mixing zone for which there will be at least two consecutive years of monitoring data available should be used to corroborate or refute impacts attributed to the mixing zone on the benthic macroinvertebrate assemblage, if downstream degradation is detected.

4.2.3 Fish Monitoring

Fish are also excellent biological indicators of stress because they integrate impacts from stressors over long time periods and great distances, and fish community structure and function are often related, either directly or indirectly, to a variety of stressors. Typical stressors that are reflected in fish assemblage degradation include temperature changes, decreased dissolved oxygen, sedimentation, pH changes, ionic concentration and salinity, reduced habitat structure, flow rates, metals, and a variety of toxins (EPA 1999; Grafe 2002a, 2002b). Unlike periphyton and benthic macroinvertebrates, however, fish are mobile and do not solely reflect conditions at their location of capture. Furthermore, fish assemblages are often directly managed and harvested by humans, so interpretations of assemblage alterations should include some information on stocking and harvest in the water body.

Idaho uses fish monitoring data to determine use attainment during bioassessments of all stream classes (Grafe 2002a, 2002b). Idaho has developed three regionally-calibrated fish indices of biological integrity for its streams. For cold water streams, a stream fish index (SFI) was created specifically for Idaho's forested ecoregion, with a second one specific to Idaho's rangeland ecoregion (Grafe 2002a). For Idaho's large river basins, the river fish index (RFI) was developed (Grafe 2002b). Adequate assessments of the fish assemblage must measure the overall structure and function of the ichthyofaunal community in order to evaluate biological integrity and identify any degradation that is occurring.

Fish bioassessment data quality and comparability are assured through the utilization of consistent methods by qualified fisheries professionals. The data to be used to calculate either the SFI or RFI for Idaho streams and rivers must satisfy the following requirements: (1) fish must be captured using at least a single pass with an electrofishing unit, (2) all fish species must be captured, identified, and recorded, (3) a physical description of the site (location, size, elevation) must be recorded, (4) length data for salmonids and sculpins must be included, and (5) electrofishing effort (duration in seconds) must be recorded. Detailed information on site selection, fish sampling, identification, data analysis and interpretation can be found in Chapter 3 of the Beneficial Use Reconnaissance Program (BURP) manual (DEQ 2007), Chapter 4 of Grafe 2002a, or Chapter 4 of Grafe 2002b.

Sampling for fish should be conducted within the same area as the other two biological assemblages. However, given the mobility and size of fish, it is more reasonable to sample long reaches (minimum of 100 m) above and below the discharge, rather than at multiple smaller sites. See DEQ 2007 for guidance on reach selection and method. Pre-discharge sampling should be conducted at least once following the methods described in Grafe 2002a and 2002b, depending on the water body size. Baseline fish assemblage characteristics should be sampled from a minimum of one reach upstream of the proposed mixing zone, and from a minimum of one reach downstream from the expected zone of influence of the mixing zone. Once the mixing zone is established, the post-discharge sampling of fish should be similar to the pre-discharge sampling regime. Fish assemblages should be monitored annually for a minimum of two years. Sampling for the life of the permit is preferable and should be considered. The discharger must show that pre- and post-discharge conditions are similar and that the discharge is not causing unreasonable interference with the beneficial uses before applying for reductions in post-discharge monitoring. For SRWs or streams that contain threatened or endangered species—particularly anadromous salmonids—monitoring requirements should be maintained at a fairly rigorous level for several years so that annual trends analyses can be performed to ensure that these highly sensitive and vulnerable species are adequately protected.

4.3 Determining Appropriate Level of Monitoring

Since not all discharges and authorized mixing zones are identical, some flexibility must be available when determining the appropriate level of monitoring. For example, the level of monitoring effort required for an SRW (see Section 4.4.1) may be more intense to ensure protection of resources and compliance with water quality standards than in other receiving waters. Furthermore, the level of monitoring merited by a small (e.g., 0.5 million gallons per day [MGD]) package plant discharging relatively less toxic materials to the lower Snake River where complete and near instantaneous mixing occurs is less than that required for a treated mine discharge to a high-elevation stream containing resident bull trout and migratory steelhead. There are a number of factors that must be taken into account when establishing the appropriate level of monitoring detail required for a given proposed or existing mixing zone. Because of the number of different combinations of factors (e.g., contaminant type, dilution factor, resident biota), it is not feasible to attempt to specify the appropriate level of monitoring for all potential mixing zone situations in Idaho. However, the critical factors to be evaluated and used to determine the appropriate magnitude of monitoring have been identified and are discussed below (Table 6). Generally speaking, DEQ will require little, if any, monitoring for facilities where a Level 1 or 2 mixing zone analysis is appropriate, unless the discharge is to an SRW. As the level of mixing zone analysis increases, the likelihood of chemical, physical, or biological ambient monitoring will increase. In the end, the best professional judgment of the permit writer and DEQ staff must be used in determining the appropriate level of monitoring to be required for any mixing zone.

Table 6. Summary of Factors to Consider in Developing Monitoring Programs

Requires Increased Monitoring	May Require Less Monitoring
Comparatively large mixing zone size	Small mixing zone (e.g., use of a diffuser in a large water body)
Mixing zone for multiple compounds (e.g., several metals), which may present additional risk (e.g., potential additive and/or synergistic effects)	Fewer or only one constituent of concern
Mixing zone to contain bioaccumulative compounds (e.g., mercury)	Mixing zone to contain nonbioaccumulative and nontoxic compounds
Species of concern occurring in the vicinity of the mixing zone	Species of concern unlikely to occur
Mixing zone in an area of concern (e.g., ORW or SRW, critical habitat, or salmonid spawning habitat)	Area to contain the mixing zone does not contain critical habitat, salmonid spawning habitat, and is not an ORW or SRW
Mixing zone in an area used as a migration route for salmon or steelhead	Comprehensive, current data suggests that an existing mixing zone has not had negative impact and that its continued existence is unlikely to have negative impact

4.3.1 Mixing Zone Size

The extent of the mixing zone should be taken into account when evaluating the monitoring that will be required. Those mixing zones in which the plume is expected to mix rapidly and take up only a relatively small portion of receiving system habitat in the vicinity of the discharge should be of less concern than larger mixing zones in which the plume mixes more slowly and the mixing zone occupies a larger portion of the available habitat. A larger mixing zone exposes a greater area of the receiving water body and resident biota to water quality conditions which do not meet water quality criteria. Thus, the larger the mixing zone, the greater potential for negative impacts to the receiving water body. Increasingly large mixing zones warrant increased monitoring. As an example, monitoring requirements for a facility where a level 1 mixing zone analysis is appropriate will not be equivalent to those for a facility that underwent a level 4 mixing zone analysis.

4.3.2 Number of Constituents of Concern

Mixing zones are established for both complex effluents that may contain a number of different metals (e.g., treated mine effluent) or relatively simple effluents which contain a single constituent of concern (e.g., chlorine in a municipal treatment plant discharge, or temperature in cooling water discharge). The level of uncertainty regarding potential impacts increases with the number of constituents for which a mixing zone has been established. Thus, the number of constituents for which a mixing zone is established should be considered in determining the potential level of impact and requisite monitoring to evaluate that potential impact. Increased monitoring may be required with an increase in the number of constituents for which a mixing zone has been established.

4.3.3 Presence of Bioaccumulative Compounds

The establishment of mixing zones for bioaccumulative materials (e.g., mercury, PCBs) is of particular concern because impacts related to bioaccumulation are often difficult to identify, manifest themselves more clearly in the biota and the sediment than in the water column, and occur over long periods (e.g., human health impacts related to consumption of contaminated fish). Except in selected cases of rapid dilution, the establishment of such a mixing zone for bioaccumulative materials should trigger bioaccumulation monitoring with fish and invertebrates for a sufficient time period to ensure the lack of impacts. A sufficient time period will be determined on a case-by-case basis and may be defined as the life of the permit. Factors to consider when determining how long the monitoring should occur may include the bioconcentration factor, concentration in the discharge, and expected concentration in the mixing zone.

4.3.4 Special Resource Waters

Discharges into water bodies designated as SRWs may require additional ambient monitoring to assess compliance with water quality standards. How compliance is assessed is beyond the scope of this document. However, the Thompson Creek Mine (DEQ 2000) provides an example of how such an assessment could be accomplished (see section 4.4.1 for a summary).

4.3.5 Species of Concern

The presence or potential presence of species of concern indicates the potential need for increased monitoring of impacts from any mixing zone. Such species of concern might be species listed as threatened or endangered under State of Idaho or federal law (e.g., steelhead trout) or other selected species of regional or local importance (e.g., cutthroat trout). Regardless, if species of special concern are known or predicted to occur, increased monitoring for impacts to that species may be required.

4.3.6 Critical Habitat

If a mixing zone is to be established in habitat determined to be critical to species of concern, additional monitoring efforts may be warranted. Such monitoring could be related to habitat impacts (e.g., siltation of salmonid spawning habitat), population-level impacts to a particular species, or general ecological condition (e.g., as assessed through benthic macroinvertebrate community monitoring). However, if the receiving system in the vicinity of the mixing zone does not contain critical habitat, less monitoring should be adequate.

4.3.7 Migratory Route

The migration of salmonids can be interrupted by the presence of elevated concentrations of compounds known to elicit avoidance responses (e.g., metals). Therefore, the establishment of mixing zones on migratory routes of salmonids must be given additional attention. Particularly, additional monitoring of salmonid passage may be required if such a mixing zone contains compounds known to elicit avoidance behavior or if the mixing zone is relatively large.

4.3.8 Availability of Existing Monitoring Data

If existing high-quality monitoring data is available at the time of permit renewal, such data should be reviewed and used in determining whether or not the existing mixing zone has the potential to degrade the resource. The existence of such data can be used to lessen the uncertainty surrounding potential impacts and to either increase (if impacts have been observed) or lessen (if no impacts have been observed) the level of required monitoring.

4.4 Interpretation and Follow-up Actions to be Taken Based Upon Monitoring Results of a Mixing Zone

The results of the physical, chemical, and biological assessment of the mixing zone’s impacts to the water body must be analyzed collectively so that differences in upstream and downstream parameters (chemical constituent, biological metric or index of biological integrity [IBI], physical habitat trait) can be attributed to the correct cause. If it is shown that the mixing zone is the most likely source of alterations in downstream condition, then actions should be taken, using best professional judgment, to alter the mixing zone permit and monitoring requirements to ensure that the designated aquatic life use is not degraded. The potential scenarios that could occur during these analyses are many. An example from a mixing zone analysis is provided in this section to illustrate the principles.

4.4.1 Case Example for a Mixing Zone in a Special Resource Water: Thompson Creek Mine (DEQ 2000)

DEQ evaluated the effects of two new discharges in the Upper Salmon Subbasin that were proposed by the Thompson Creek Mine. One of the proposed discharges was to the Salmon River, which is designated as a SRW. The mixing zone analyses included evaluations of site and regional water and sediment chemistry, biological conditions in the receiving waters, whole effluent toxicity testing, potential fish avoidance around the mixing zones (zone of passage), risk of adverse bioaccumulative effects of mercury and selenium, relative flows of effluents and receiving waters, variations of flow by width and depth within the receiving waters, and extensive hydrodynamic modeling of effluent plume dispersion and dilution under varying flow and pollutant scenarios. In addition, the document recommended biological monitoring as well as strategies for data interpretation and follow-up actions that could be taken based upon monitoring results. A summary of the data interpretation and potential follow-up actions is below.

Macroinvertebrates: Abundance or Taxa Richness of Mayflies

If upstream-downstream sampling sites have similar substrates, stream size, aspect, and other habitat features, abundance or taxa richness of mayflies would be expected to be similar. If hypothesis tests indicate that downstream differences or declining trends of abundance or taxa richness of mayflies occur compared to the upstream reference sites, then the causes should be investigated. Investigations should consider more frequent chemical sampling to better define waterborne potential exposure routes, exposure through sediments or auwfuchs, *in situ* toxicity testing, or sediment toxicity testing. Other actions to be considered include increasing the frequency of WET testing to quarterly with both invertebrates and fish. If WET testing was ongoing, but not showing toxicity despite declining mayfly taxa richness or abundance, then receiving water trigger concentrations should be re-evaluated or additional safety factors applied.

Macroinvertebrates: Multimetric Scores

If scores are lower downstream than upstream, the component metrics should be considered, and the components causing the reduced scores should be evaluated. If the evaluation indicates water quality is responsible for depressing the scores, further investigations to identify and remedy the causes should be undertaken. These investigations could take the form of a toxicity identification evaluation (TIE) or a toxicity reduction evaluation (TRE) (Norberg-King et al. 2005). See also the Stressor Identification Guidance document (EPA 2000a, available at http://www.epa.gov/waterscience/biocriteria/stressors/stressorid.html).

Periphyton

If multimetric scores are lower downstream than upstream, the component metrics should be considered, and the components causing the reduced scores should be evaluated. Patterns discerned through descriptive and exploratory statistics should be interpreted. If the evaluation indicates water quality is responsible for depressed scores, further investigations to identify and remedy the causes should be undertaken. Again, these could take the form of a TIE or a TRE (Norberg-King et al. 2005). See also the Stressor Identification Guidance document (EPA 2000a).

Fish

Results of hypothesis tests and trends assessment should be interpreted, explained, and, if necessary, investigated further. If multimetric scores are lower downstream than upstream, the component metrics should be considered, and the components causing the reduced scores should be evaluated. If the evaluation indicates water quality is responsible for depressed portions of the assemblage, further investigations to identify and remedy the causes should be undertaken. If, for example, trout densities are lower below the discharges than above, and environmental covariates such as physical habitat features or temperature differences cannot fully explain the differences, DEQ will presume that the apparent effects are due to the discharges.

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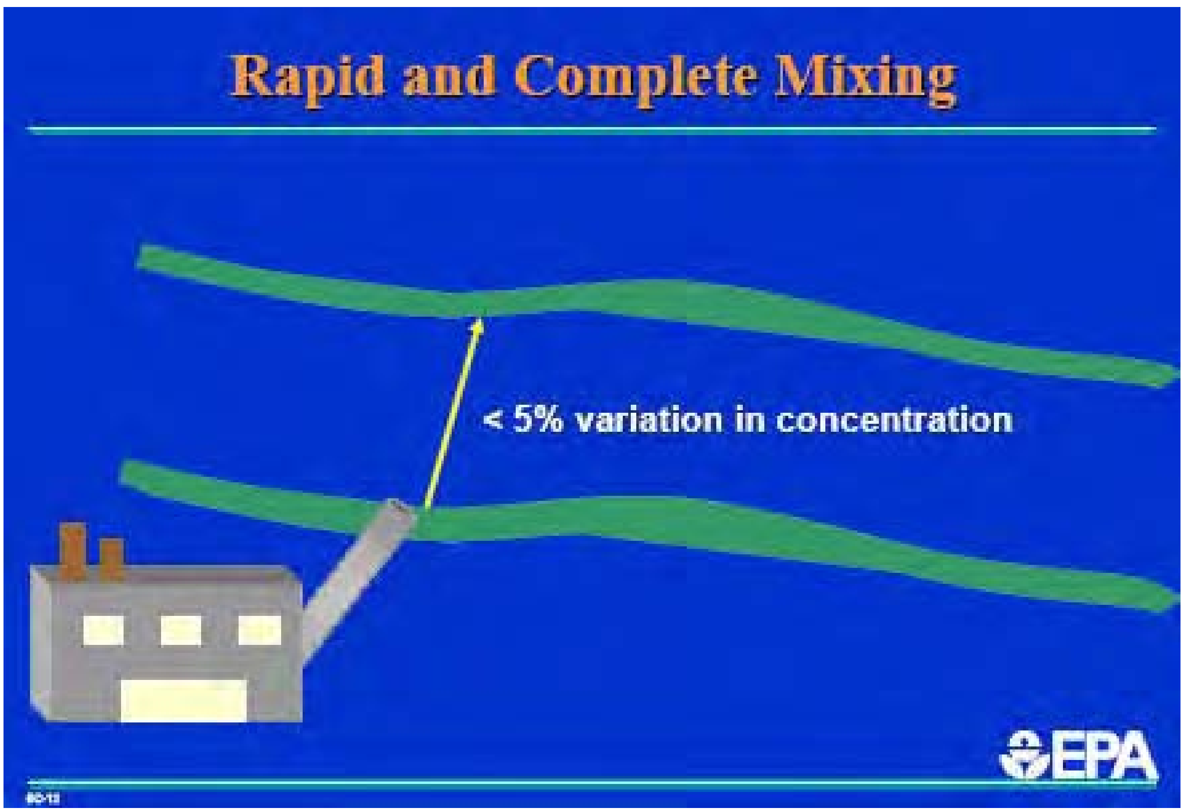
5.0 INCOMPLETE VERSUS COMPLETE MIXING

5.1 Definitions of Incomplete and Complete/Instantaneous Mixing

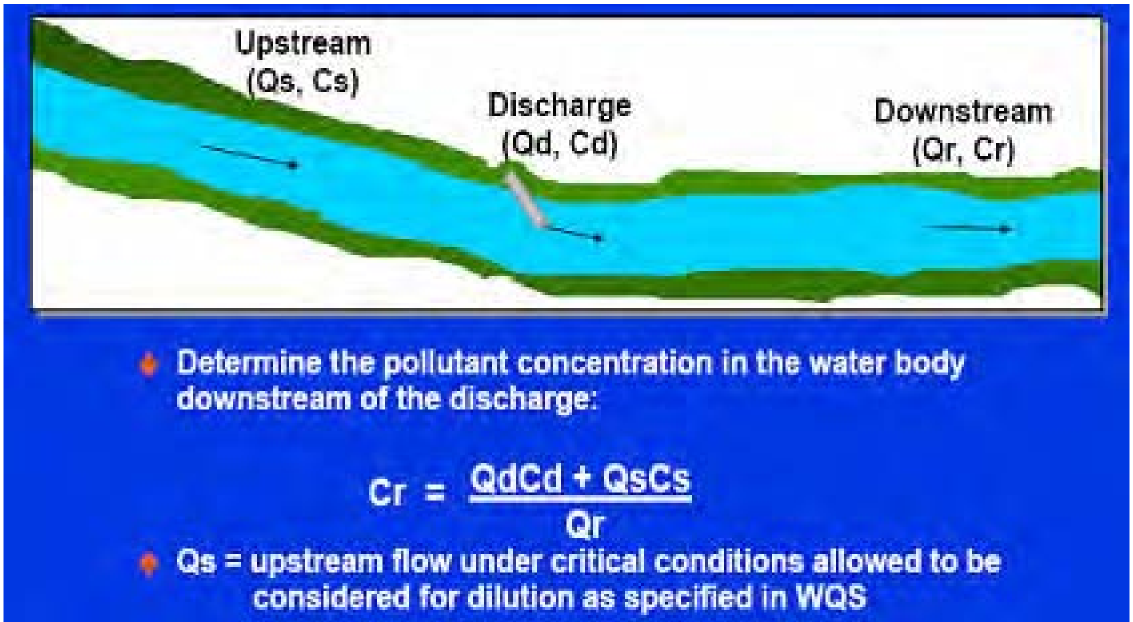
Historically, many states and EPA regions have adopted a mass balance approach to evaluating mixing and establishing effluent limitations for discharges to rivers and streams in NPDES permits. Under this approach, the maximum potential flow of the discharge and the portion of the critical low flow in the receiving water, along with the effluent and background receiving water characteristics, are used to determine effluent limitations. *No mixing zone size is estimated.* This approach is based on the concept of complete mixing, i.e., where the discharge becomes completely mixed with the receiving water in the immediate vicinity of the point of discharge. In practice, complete and near instantaneous mixing exists when lateral variation in concentration in the direct vicinity of the outfall is small (e.g., less than 5%; see Figure 5). Except in an effluent-dominated water body, “complete mixing” does not, in practice occur; i.e., there will be an area in the water body where water quality criteria are exceeded. It is, however, possible to have near instantaneous mixing, particularly in a river or stream with very low discharge and very high receiving water flows. Mixing can be enhanced through the use of diffusers located across a portion of the stream or river width.

Figure 5. Complete and Near Instantaneous Mixing between Effluent and Ambient River Flow (from EPA Permit Writer’s Training Course Notes)



Where there is complete and near instantaneous mixing, permit writers may consider up to a specified percentage of a critical low flow in water bodies for dilution when calculating effluent limitations. Figure 6 shows the determination of the completely mixed concentration of the pollutant based on 100% of the receiving water flow. As discussed in sections 2.5.1 and 3.4.7, DEQ may allow up to 25% of the critical low flow; however, efforts should be made to make the mixing zone as small as practicable.

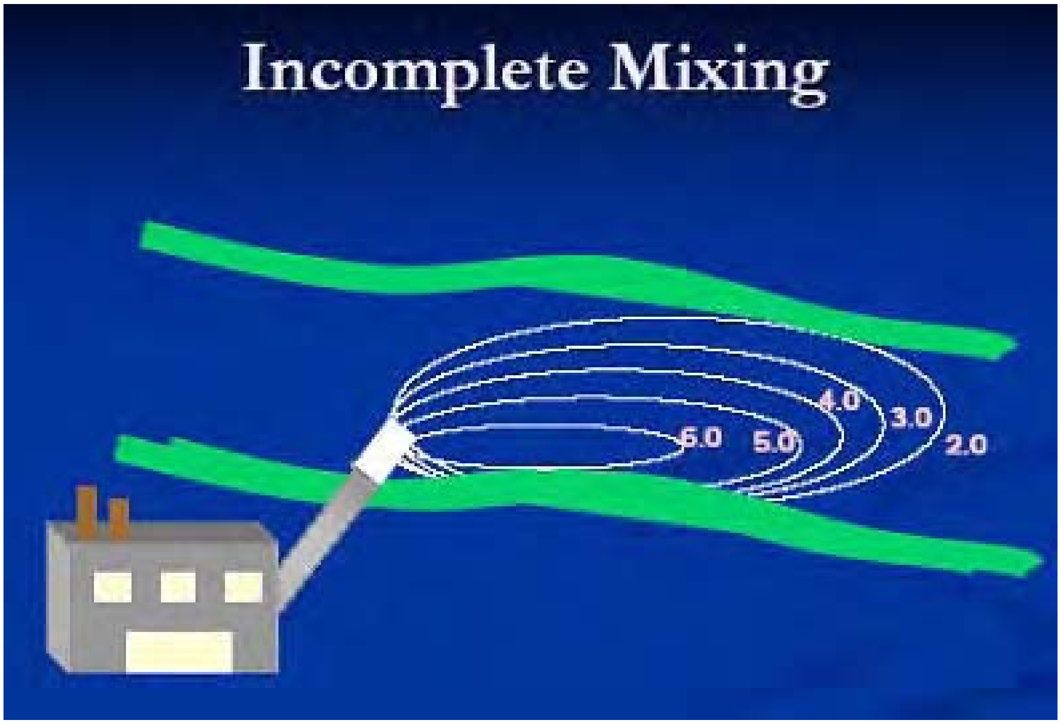
Figure 6. Mass Balance Calculation to Determine the Completely Mixed Concentration (from EPA Permit Writer's Training Course Notes)



Notes
Cs: upstream river concentration
Qd: discharge flow
Cd: discharge concentration
Qr: downstream flow

In practice, "incomplete mixing" means that there will be a discernible area within the receiving water where mixing occurs (see Figure 7). This is generally the case where initial mixing associated with the momentum and buoyant flux of the discharge ceases and the mixing process is dependent on the ambient hydrodynamics (e.g., turbulences within the water body). In this case, a dilution factor is determined through either modeling, based on the nature of the limitations, and/or using low flow calculations. The size and shape of the mixing zone are then shown by modeling.

Figure 7. Incomplete Mixing between Effluent and Ambient River Flow (from EPA Permit Writer's Training Course Notes)



5.2 Implementation Policy Guidance

If the applicant can demonstrate that complete and near instantaneous mixing will occur, then a mixing zone analysis may not be necessary. In such situations, it is reasonable that the permit writer utilize a mass-balance approach with a specified proportion of the critical low flow volume. If requesting more than 25% of the critical low flow, the applicant must provide documentation demonstrating that such increased dilution volumes will not impact the beneficial uses of the receiving water body.

If complete and near instantaneous mixing does not occur, a mixing zone analysis will likely be required and subsequently reviewed by DEQ. If the size limitations in Idaho water quality standards are exceeded, then the applicant is expected to provide adequate documentation demonstrating that the mixing zone will not cause unreasonable interference with or danger to existing beneficial uses of the receiving water body.

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6.0 MIXING ZONE DETERMINATIONS/WATER QUALITY MODELING

6.1 Background on Mixing Zone Modeling

The picture of mixing between wastewater and receiving water can be visualized as follows. Consider wastewater discharged horizontally as a jet from a single round port or a series of jets from ports spaced at equal distances along a diffuser. If the wastewater has a lower density than the surrounding receiving water, then the resulting buoyancy force deflects the jet(s) upward, forming plumes, which are swept downstream by the ambient current. The plume(s) entrain ambient water as they rise, causing them to dilute and decreasing the density difference between them and the ambient water. If the ambient water is stratified, then its density at the depth of the ports is greater than that near the surface. The greater density ambient water which was entrained initially, and the rising, expanding plumes can reach a level where their density is the same as the surrounding water (i.e., neutral buoyancy). If the receiving water is not stratified, then its density is the same throughout the water column. The initial jet characteristics of momentum flux, buoyancy flux, and outfall geometry influence the jet trajectory and mixing. This region is referred to as the “near-field,” and encompasses the buoyant jet subsurface flow and any surface or bottom interaction, or in the case of stratified ambient water, any terminal layer interaction. In this region, designers of the outfall can usually affect the initial mixing characteristics through appropriate manipulation of design variables.

As the turbulent plume travels further away from the source, the source characteristics become less important. Conditions existing in the ambient environment will control trajectory and dilution of the turbulent plume through buoyant spreading motions and passive dispersion due to ambient turbulence. This region is referred to as the “far-field.”

It should be pointed out that the distinction between near-field and far-field is made purely on hydrodynamic grounds. It is unrelated to any legal mixing zone definitions that address prescribed water quality criteria. In many practical cases, the legal mixing zone may, in fact, include only near-field hydrodynamic mixing processes. But that does not have to be so. For example, buoyant jet mixing in a deep environment with cross flow may extend far beyond a legal mixing zone that is defined by State regulations. As a counter example, a small source in a strong cross flow may rapidly enter the passive far-field dispersion region (in the form of a shore-hugging plume) well before the edge of a legal mixing zone. Thus, in principle, the entire gamut of mixing processes, ranging from the near-field to the far-field, should be considered for individual mixing zone analyses.

6.1.1 Discharge-induced Mixing

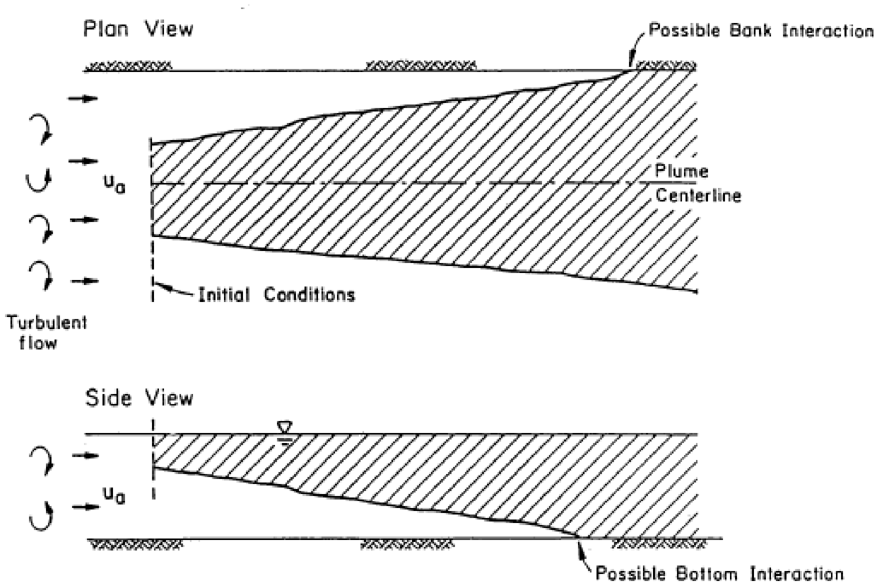
The first stage of mixing is achieved by discharge jet momentum and buoyancy of the effluent. It is particularly important in lakes, impoundments, and slow-moving water bodies, since ambient mixing in those systems is minimal. In the absence of near-field instabilities, horizontal or nearly horizontal discharges will create a clearly defined jet in the water column that will initially occupy only a small fraction of the available water depth. When the discharge flow encounters a boundary such as the surface, the bottom, or an internal ambient density stratification layer, the near-field region ends and the transition to the far-field begins. In simple terms, the near-field region is typically the region that is controlled by the characteristics of the discharge itself (discharge flow rate, port diameter, etc).

6.1.2 Ambient-induced Mixing

Beyond the zone of discharge-induced mixing, mixing is controlled by ambient turbulence. If there is no discharge-induced vertical mixing associated with the jet action of the discharge, then mixing over the depth of the water body must be accomplished by ambient mixing. For a neutrally buoyant, soluble effluent discharged with low velocity at the surface or at the bed of a stream, the flow distance required to achieve complete vertical mixing is on the order of 50 to 100 times the depth of water in that portion of the channel where the effluent is discharged (Yotsukura and Sayre 1976). For a discharge that is either lighter (positively buoyant) or heavier (negatively buoyant) than the ambient water, but still has no excess momentum, the flow distance for mixing over the depth will be greater. In the normal case with a high-velocity jet designed to prevent lethality in the mixing zone, mixing over the depth will be accomplished primarily by jet action, and the distance required for this vertical mixing will be much shorter (EPA 1991).

Once the momentum flux from the effluent is exhausted in the receiving water, continuing dilution would come from ambient-induced mixing. Under this circumstance, the advective and dispersive mass transport in the receiving water would play a major role in providing additional dilution for the effluent. Once the discharge interacts with a vertical boundary, the mixing processes are primarily a function of the ambient conditions characterized by the longitudinal advection of the mixed effluent by the ambient velocity. The discharge in the far-field loses its "memory" of its initial conditions, and mixing is now mainly a function of the ambient conditions. The far-field region (see Figure 8) is the region controlled by ambient conditions (ambient velocity and density field, cross-sectional area, etc).

Figure 8. Far-field Plume, Passive Ambient Diffusion Processes (Jirka et al. 1996)



6.2 Available Models

A wide variety of mixing zone models exists for evaluating the mixing behavior and plume dynamics of a point source discharge. There is no single model that is appropriate for every discharge situation. Each model has its own set of strengths and weaknesses. It may be appropriate to use more than one model to evaluate mixing and dilution if more than one is available to the modeler. Using an EPA-recognized and supported model is typically a good choice, as these have undergone review and scrutiny by the profession. DEQ prefers EPA-supported models such as PLUMES and CORMIX; however, DEQ may consider other models if they are more suitable for the site-specific conditions. As such, more complex modeling systems such as EFDC (Environmental Fluid Dynamics Code) and a simple, analytical model are included in this technical procedures manual as alternative modeling approaches. If the applicant proposes to use a model not discussed in this manual, it is highly recommended that the applicant discuss this with DEQ.

6.2.1 Near-field Dilution Models

CORMIX and PLUMES are currently the two most widely used models in mixing zone calculations. Other available but less widely applied mixing zone models include VisJet[1] and DESCAR[2]. VisJet is a Lagrangian integral model for near-field mixing analysis for stable submerged single port and multiport diffuser discharges that does not consider near-field wake and Coanda dynamic attachments or density current behavior after buoyant jet mixing. DESCAR is a one-dimensional length scale model for submerged single port discharges that is restricted to vertical or horizontal port orientations. DESCAR does not consider near-field benthic impacts or density current behavior.

The empirical models, like PLUMES, predict initial dilution by stringing together a series of building blocks called length scales. A length scale is a scaling estimate based on dimensional analysis arguments that identifies the region of influence of a particular physical process. Each length scale is a distance along the trajectory where one parameter predominates (i.e., controls the flow). Once strung together by this analysis, the length scales should describe the relative importance of all parameters—discharge volume flux, momentum flux, buoyancy flux, ambient cross flow, and density stratification—throughout the trajectory. For example, the solution for a pure jet can be applied as an approximate solution to that portion of a buoyant jet in a cross flow where jet momentum dominates the flow. Likewise, the results for a pure plume can be applied to the buoyancy-dominated regions for the buoyant jet. The length scales are linked by appropriate transition conditions to create a path for the trajectory through the completion of initial dilution.

CORMIX is an EPA-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. CORMIX emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry. The CORMIX methodology contains systems to model single-port and

CORMIX is available for free testing and evaluation from Mixzone, Inc. at http://www.mixzon.com/.

[1] http://www.aoe-water.hku.hk/visjet/visjet.htm
[2] http://www.canarina.com/outfall.htm

multiport diffuser discharges, as well as surface discharges of conventional or toxic pollutants. Effluents considered may be conservative, non-conservative, or heated, or contain suspended sediments. Advanced computer-aided design (CAD) systems provide documented water quality modeling, NPDES regulatory decision support, visualization of regulatory mixing zones, and tools for outfall specification and design.

CORMIX uses a data-driven approach to simulation model selection. It is comprised of about 50 flow modules, each with their own formulae or algorithms, and more than 100 possible distinct flow classifications. Based on the input data the user enters to describe the discharge and ambient environment, the system selects the proper choice of model to represent the physical mixing processes likely to occur within the mixing zone. The model selection procedure is both automated and fully documented by a rule-based system that screens the input data for internal consistency and compliance with model formulation assumptions. The system contains logic to reject cases where no reliable model exists for the given discharge situation, and will warn the user in cases where the simulation occurs but results may be unreliable. The internal model selection procedure is fully documented by extensive, published, peer-reviewed scientific research. Statistical tools are readily available to evaluate model performance with available laboratory and field data on mixing predictions.

PLUMES (Baumgartner et al. 1994) is another initial dilution model available for analyzing mixing zones. It is freely available from the EPA Center for Exposure Assessment Modeling (CEAM) at http://www.epa.gov/ceampubl/swater/vplume/index.htm. PLUMES has the capability of listing salinity, temperature, and current variations at different depths. Its version for Microsoft® Windows, called Visual Plumes (VP), is being supported by CEAM in Athens, Georgia (Frick et al. 2003). VP simulates single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. VP addresses the issue of model consistency in a unique way, by including other models in its suite of models. In this way, it promotes the idea that in the future, modeling consistency will be achieved by recommending particular models in selected flow categories. VP includes the following models:

- Davis, Kannberg, and Hirst model for Windows (DKHW) that is based on the universal Davis, Kannaberg, and Hirst density model (UDKHDEN) (Muellenhoff et al. 1985),
- Prych, Davis, and Shirazi surface discharge model (PDS) (Davis 1999),
- three-dimensional updated merge model (UM3) based on the updated merge model (UM), and
- near field model (NRFIELD) based on the Roberts, Snyder, and Baumgartner length scale model (RSB)

These models may be run consecutively and compared graphically to help verify their performances.

CORMIX and PLUMES both use similar jet-integral approaches to simulate near-field mixing zones in stable discharge conditions without dynamic attachments. In these cases, both CORMIX and PLUMES can be applied, and they will generally give similar near-field dilution estimates, well within each other and the scatter of available field and laboratory data. CORMIX uses the jet-integral model CorJet for near-field predictions. In PLUMES, the models UM3, DKHW, or

NRFIELD may be applied. PLUMES should only be used where dynamic attachment and discharge instability are not issues. In the cases where dynamic attachment, discharge instability, or density current behavior are issues within the mixing regulatory zone, only CORMIX has the capability to simulate the relevant physical processes.

Table 7 lists typical data needed to run CORMIX and PLUMES models.

Table 7. Data Needs to Run CORMIX and PLUMES Mixing Zone Modeling Software

Category of Data	Data Items
Ambient conditions	Width of water body at discharge point (m)
	Depth of water body at discharge point (m)
	Average depth of water body at discharge point (m)
	Ambient velocity and density profile
	Bottom roughness
Discharge conditions for single port discharges	Nearest bank (right or left) to the outfall looking downstream
	Distance from nearest bank to discharge (m)
	Port diameter (m)
	Contraction ratio (if known)
	Effluent density
	Height of discharge above stream bottom (m)
	Discharge horizontal angle (σ)
	Effluent flow rate (million gallons per day [MGD])
Discharge conditions for submerged multiport diffusers	Diffuser length (m)
	Nearest bank (right or left) to the outfall looking downstream
	Distance from nearest bank to first diffuser port (m)
	Distance from nearest bank to last diffuser port (m)
	Total number of diffuser ports
	Diameter of a single diffuser port (m)
	Distance between adjacent ports (i.e., port spacing) (m)
	Height of diffuser ports above streambed (m)
	Diffuser port contraction ratio (if known)
	Submerged endpipe or submerged multiport diffuser
	Discharge density
	Discharge concentration
	Discharge port vertical angle (θ)
	Discharge horizontal angle (σ)
	Angle between diffuser line and ambient current (γ)
	Relative angle between port centerline projection on horizontal plane and diffuser axis(β)
	Effluent flow rate (MGD) or velocity
Conditions for surface (or shoreline) discharges should also be included	Discharge channel depth (m)
	Discharge channel width (m)
	Angle between surface discharge and ambient current (σ)
	Discharge density
	Discharge flow rate (MGD) and/or velocity
	Local ambient depth at discharge location (m)
	Bottom slope at discharge location

For a brief description of the data items above, the modeler should consult the CORMIX website at http://www.cormix.info/glossary.php. Data for the ambient conditions are usually obtained from the discharge outfall location. The discharger applying for a permit should submit the data and information on the discharge conditions.

Both CORMIX and PLUMES are steady-state mixing zone modeling frameworks. For systems where mixing zone dilution under dynamic flow conditions is necessary, it may be desirable to apply a dynamic modeling framework to achieve more efficient and realistic system analysis. A typical case of dynamic flow condition is in a river where the flow velocity and direction as well as the water depth continuously change with time, making it hard to define a well-represented critical flow condition for steady-state mixing zone analysis. Although a steady-state mixing zone model such as CORMIX can potentially be applied to analyze such a system, it would involve dividing the time-variable water flows into a large number of constant flows, and then implementing as many steady-state model runs as the number of constant flows to obtain an understanding of the dynamic behavior. This process can be very cumbersome, such that a dynamic modeling framework capable of analyzing dynamic flows in a single model simulation would be desired for efficiency of modeling analysis. One such a modeling framework for dynamic near-field simulations is EFDC, available at http://www.epa.gov/ceampubl/swater/efdc/index.htm (Hamrick 1996, Hamrick and Wu 1997).

While EFDC was originally designed for hydrodynamic and fate and transport modeling of contaminants in ambient waters, it has two modules for the simulation of near-field mixing, as well as the capability of simultaneously simulating far-field effects. The first module simulates multiple single port discharges, using an enhanced version of the Lagrangian buoyant jet and plume model by Lee and Cheung (1990), generalized to account for arbitrary orientation of the plume discharge axis with the ambient current. Since EFDC simultaneously simulates the far-field hydrodynamics, it provides a very realistic representation of ambient current and stratification conditions for use in the near-field modeling. The near-field and far-field concentration fields are internally coupled in a mass-conserving manner during simultaneous near- and far-field fate and transport simulations (Tetra Tech 2002). This approach is particularly advantageous for applications where a wide range of ambient conditions must be considered. Also, since multiple near-field discharges can be simulated in a single model run, ambient conditions associated with all discharges are properly accounted for in determining the impact of individual discharges.

The second module in EFDC is based on a volume source and is useful for simulating high velocity single- and multi-port diffusers having nearly horizontal discharges. In this formulation, the turbulent entrainment dynamics of the discharge are represented using EFDC's internal turbulence closure model. This module has been used extensively for power plant cooling water discharges and large wastewater discharges (Hamrick and Mills 2001).

A fully coupled hydrodynamic and near-field mixing zone modeling framework such as EFDC also offers the advantage of better representing more complex and irregular stream geometric conditions. CORMIX and PLUMES assume that the receiving water body is rectangular or can be reasonably approximated in a rectangular shape. Although this is a reasonable assumption for a majority of water bodies, it can impose a significant limitation for systems where the receiving water body has highly irregular, complex geometric features. For example, if the depth of the receiving water changes significantly from one location to another within the mixing zone area in both longitudinal and lateral directions, and the spatial variability of the water depth is not regularly distributed, the water body cannot be approximated as a regular shape such as a rectangle. In such cases, CORMIX and PLUMES may not be capable of providing accurate, realistic representation of the real system. In contrast, EFDC can be developed to represent the complex geometry in two- or three-dimensional configurations to more realistically simulate the flow and mixing dynamics.

Additional information on EFDC is presented in the next section.

6.2.2 Far-field Modeling Frameworks

The far-field models are designed to track the contaminant concentration along the plume of the discharge in areas of the receiving water where mixing is dominated by ambient fluid turbulence. The CORMIX model is recommended as a primary modeling framework, not only for near-field analysis, but also for far-field simulation, since it has the capability of performing both near- and far-field mixing zone calculations.

While the CORMIX is a modeling framework applicable to most real-world conditions, EFDC serves as an alternative for applications in conditions where fully dynamic simulation and complex instream hydrodynamics need to be considered. EFDC has evolved over the past two decades to become one of the most widely used and technically defensible hydrodynamic models in the modeling field for one-, two-, or three-dimensional configurations. Table 7 presents key information on the EFDC model. Users may consult the EFDC manual for data needs of specific applications. The EFDC manual can be downloaded from http://www.epa.gov/athens/wwqtsc/html/efdc.html.

Table 8. EFDC Model Information

Current Version	1.0
Release Date	July 9, 2002
Operating System	Windows 95/98/ME/2000/XP
Intended Audience	Environmental engineers/scientists, regulatory agencies
Key Words	Hydrodynamics, temperature, salinity, stratification, NPS related, NPDES, point source(s), surface water, test/analysis, TMDL related, near-field, far-field
Media	Lakes, rivers, estuaries
Pollutant Types	Hydrodynamic transport, links with Water Quality Analysis Simulation Program (WASP6)

6.2.3 Analytical Solution Approach: A Simple Alternative for Special Conditions

As the mixing zone modeling of large wastewater flows associated with significant momentum has been completed for many major point sources, much of the focus of mixing zone modeling is now centered on small wastewater flows with insignificant momentum, and thereby minimal initial dilution. The analysis presented in this section is primarily designed for plumes resulting from wastewater flows with negligible momentum and buoyant flux and discharging into vertically well-mixed water bodies with simple flow and channel conditions. With negligible discharge momentum and buoyant flux, it is reasonable to neglect the near-field mixing process, hence attributing the total mixing solely to the passive ambient mixing process. The key mechanisms characterizing the plume in a river, for example, are advective and dispersive mass transports, resulting in interactions between the ambient river flows in the longitudinal direction and the dispersion process in the lateral direction, which in turn controls the length and width of the plume. The analytical solution can be found for rivers in Fischer et al. (1979), which is described in Appendix D. Data needs for this modeling approach are shown in the case studies (Appendix G).

To determine whether the simple analytical approach is appropriate for a specific mixing zone analysis case, one must estimate the momentum flux associated with the discharge and make sure it is insignificant. Appendix E presents the technical details of momentum flux estimation, and the momentum flux estimation method is illustrated using four examples. As shown in Table E-1, the momentum flux in the four sample discharges is very small, indicating minimum momentum-induced initial dilution. Also, the receiving water depths in all these cases are shallow and non-stratified; hence, along with the insignificant momentum flux, the buoyancy effect can also be assumed to be small. (Note that buoyancy effect is most significant in deep ocean outfalls, which do not exist in Idaho and may be neglected.) Under such conditions, the mixing process is governed by the ambient advection and dispersion. Although CORMIX and PLUMES can be applied to these cases, the analytical approach can also be considered an appropriate, cost-effective alternative. The mixing zone model runs for a number of the discharges using the analytical solution approach are summarized in Table 8. Results in Table 8 show the significantly smaller *y* (distance across the river) against the large *x* (distance along the shoreline), indicating the shore-hugging (relatively narrow and long) plumes due to the strong ambient current (u_a) in all cases.

As a matter of practice, where the length of the momentum-induced area is less than 1-2 meters and the momentum-induced mixing dilution factor is less than 1, application of the analytical tool can be considered.

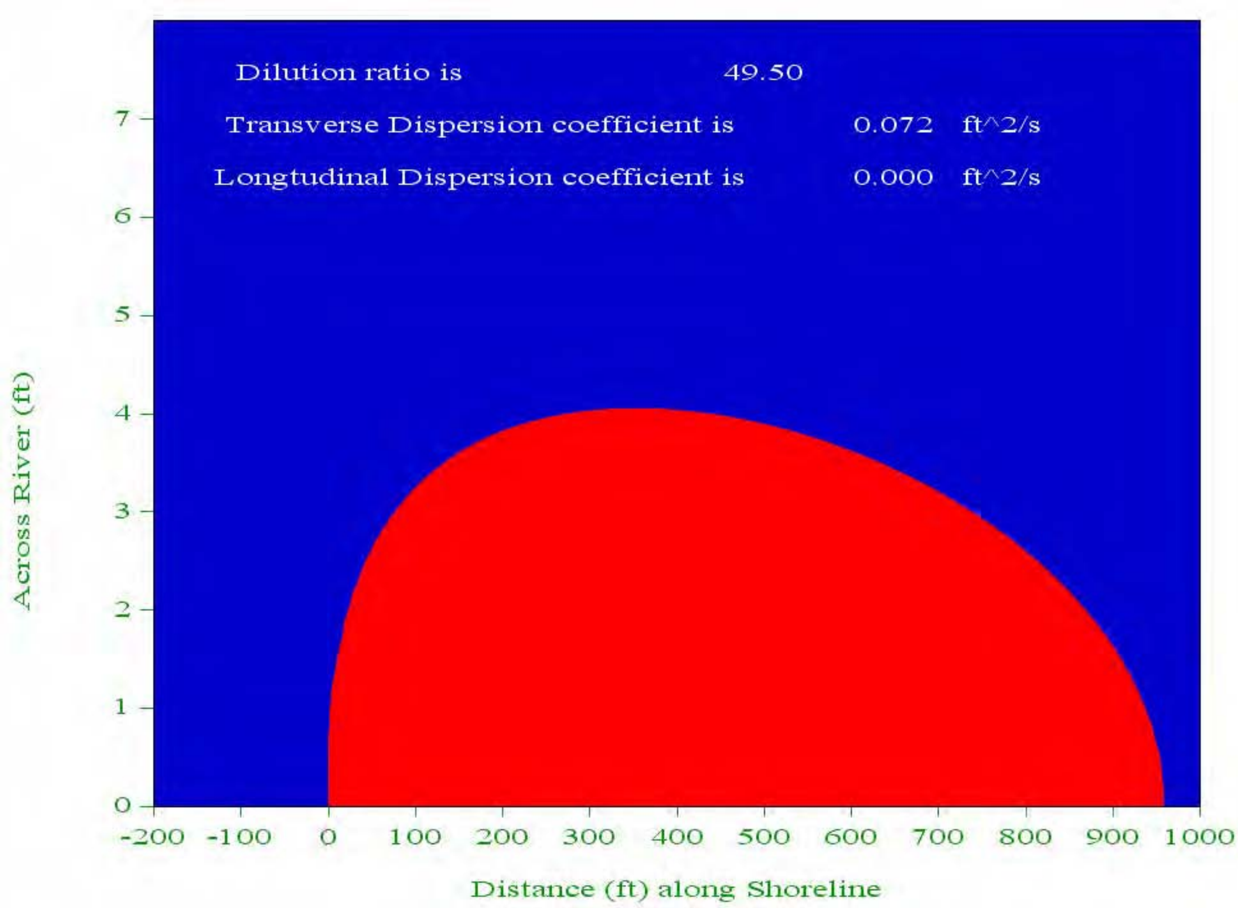
Table 9. Summarized Results of Analytical Solution Model Runs

Site	Q_o (MGD / m^3/s)	u_o (m/s)	Q_a (cfs / m^3/s)	u_a (m/s)	Dilution	*x* (ft / m)	*y* (ft / m)
1	1.0 / 0.045	0.198	909 / 25.75	0.944	49.5	960 / 290	4.1 / 1.25
2	5.7 / 0.250	0.213	4140 / 117.3	0.448	29	8800 / 2680	27 / 8.23
3	2.5 / 0.110	0.829	30.6 / 0.866	0.609	7.5	10200 / 3415	12.5 / 3.81
4	0.32 / 0.014	small	6.60 / 0.187	0.305	5	730 / 220	4.0 / 1.22

Q_o: wastewater flow rate, u_o: discharge velocity of the wastewater, Q_a: ambient river flow rate, u_a: average river velocity, *x*: distance along shoreline, *y*: distance across river.

The results for Site 1 are displayed in Figure 9, listing key model parameters: the dilution ratio required (i.e., 49.5) and the transverse dispersion coefficient (0.072 ft^2/s). Note that the longitudinal dispersion coefficient is 0 for a riverine condition in this case. The boundary of the red zone is for the calculated dilution ratio of 49.5.

Figure 9. Summary of Mixing Zone Model Runs Using Analytical Solutions



6.2.4 Model Selection

Table 10 summarizes the key features of the recommended mixing zone models.

Table 10. Mixing Zone Model Summary Matrix

Model Characteristics		Analytical	CORMIX	EFDC
Receiving Water Characteristics	Non-stratified	+	+	+
	Stratified	-	+	+
	Simple bathymetry	+	+	+
	Irregular, complex bathymetry	-	-	+
Flow Domain	Near-field	-	+	+
	Far-field	+	+	+
Discharge Characteristics	Insignificant discharge momentum flux	+	+	+
	Significant discharge momentum flux	-	+	+
	Insignificant discharge buoyant impact	+	+	+
	Significant discharge buoyant impact	-	+	+
Temporal	Steady-state analysis	+	+	+
	Fully dynamic time variable simulation	-	-	+
Data Requirements		1	2	3
Cost		1	2	3
Experience Needed		1	2	3
Effort Required*		1	2	3
Software Availability		A	C	A

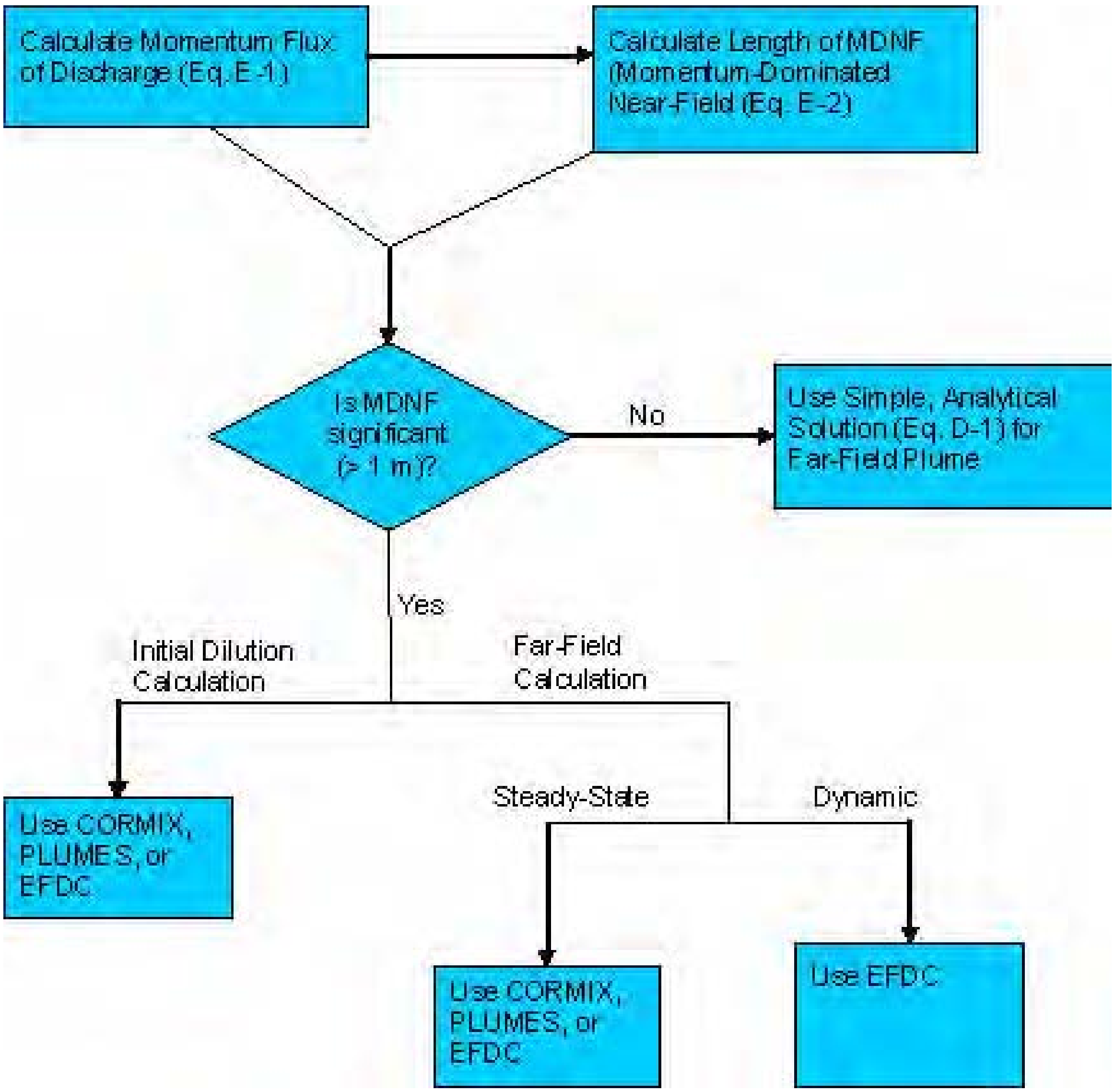
Key
+ = applicable
- = not applicable
1 = minimal
2 = intermediate
3 = significant
* Note: Effort Required: 1 = short duration (days); 2 = intermediate (weeks); 3 = significant (months)
A = public domain, model and source code available at no cost
C = evaluation model available at no cost upgrades available for a fee

In real-world practice, the decision on model selection should be based on factors including discharge characteristics, receiving water conditions, and discharge-ambient water interaction. Discharge characteristics include single pipe or multiple ports. Further, location of the discharge—whether it is submerged or on the surface—is another key factor. Another factor is the significance of the momentum flux of the discharge. Wastewater flow plays a major role in selecting a suitable model for mixing zone analysis, as the discharge flow contributes directly to the effluent momentum flux. One possible approach to selecting a model is to calculate the spatial domain of the momentum-dominated near-field (MDNF) (see Appendix E), within which the momentum flux is sufficiently strong to induce initial dilution upon impact with the receiving water. Appendix E also yields the dilution ratio to be achieved by the effluent at the edge of the MDNF. If the MDNF is sufficiently large and the initial dilution is significant within the MDNF, the near-field mixing zone models such CORMIX, PLUMES, or EFDC should be used to quantify the near-field mixing. The follow-up turbulence-induced mixing can be simulated with a far-field model, if needed.

If the discharge has a very small MDNF area (less than 2 m) and insignificant dilution (dilution factor less than 1), the near-field mixing can either be simulated using CORMIX, PLUMES, or EFDC, or alternatively, neglected. In this case, it is possible to apply the simple analytical model as a viable alternative to obtain a reasonable result (Medina et al. 2003).

The mixing zone model selection process is summarized in Figure 10.

Figure 10. Mixing Zone Model Selection Flow Chart



6.3 Data and Information to Support Mixing Zone Modeling Analysis

The reliability of the predictions from any of the modeling techniques depends on the accuracy of the data used in the analysis. The minimum data required for model input include receiving water flow, effluent flow, effluent concentrations, and background concentrations. Appendix C lists the type of information needed for each level of analysis.

6.3.1 Stream Flow

Information on how to calculate long-term stream flows, including critical low flows such as the 7Q10, is presented in Section 2.5.1.

6.3.2 Effluent Characteristics

For publicly owned treatment works (POTWs), the facility design flow is used in the mixing zone analysis. For other types of dischargers (e.g., industrial) the maximum recorded flow during the previous five year permit term is typically used. An exception would be where facility changes have occurred such that the maximum flow is highly unlikely to be reached in the future (e.g., permanent shutdown of a portion of an industrial facility). In such cases, the maximum flow observed (or anticipated) under the current or planned future operation conditions would be used.

Effluent concentration is often used in a mixing zone determination, i.e., what mixing zone would be required based on the composition of the effluent. To make such determinations, EPA and DEQ follow the methodology described in the TSD (EPA 1991) to project the maximum possible effluent concentration from the maximum observed effluent concentration. For a new permit issuance, the maximum observed concentration is obtained from the NPDES permit application. For a reissued permit, the maximum observed concentration is the highest level observed during the previous five year permit term.

6.3.3 Hydrographic/Receiving Water Data

Ideally, data should include the following:

- seasonal temperature profiles for the full depth of the water column
- currents at various depths from the surface to 5 m above the ports, including:
    - direction and orientation
    - maximum, minimum, and 10 percentile maximum and 10 percentile minimum currents
    - the presence of eddy currents, which could retain the effluent in the area
    - flushing rates of the water body

In practice, data may be very limited, so as much as is reasonable is expected, with estimated values for data that cannot be collected. Also, for many discharges, data for currents at various depths may not be feasible, or the receiving water may be less than 15 feet deep; in either case, either the surface measured or estimated currents will suffice. Other needed receiving water data include stratification, velocity/current distributions, and the physical dimensions of the receiving water. In many situations, existing ambient water data to support the modeling analysis is limited. If this is the case, field sampling must be carried out to provide the necessary data for the mixing zone modeling analysis. The following paragraphs briefly describe sampling work that may be required to gather stream geometry data and hydraulic data.

Channel geometry data are used to define the stream configurations, regardless of the particular model being used. This includes simplistic models, analytical solutions, and near-field and far-field numerical models. The basic types of channel geometry data include:

1. Variation of channel width and cross-sectional area with depth.
2. Bottom slope (or bed elevations).
3. Variation of wetted perimeter or hydraulic radius with depth.
4. Bottom roughness coefficient (Manning's n).

Variation of water depth with flow is also important but will be discussed in the next paragraph. The four parameters listed above are typically assumed constant for the section of the river being modeled (i.e., the river is modeled as a rectangular box). Length and average slope over long distances can be determined from topographic maps, while the other variables usually require field surveys. The level of detail required in describing the stream geometry depends on the amount of variability in the system. For streams which have uniform slopes and cross-sections over the study area, only a few transects will be necessary. However, in areas where the channel geometry varies widely, the stream should be divided into a series of representative reaches, and sufficient transects should be measured along each reach to adequately characterize the geometry. Three to five cross-sections could be measured along each reach, and the results could be averaged to define the reach characteristics for the channel. At a minimum, one representative cross-section should be measured in each reach. Some pool and riffle streams may require dye studies and measurement of as many cross-sections as possible to obtain adequate stream geometry.

Hydraulic data are needed to define the velocities, flows, and water depths for mass transport calculations. Sufficient data are necessary to characterize the hydraulic regime throughout the study area. Depth-flow curves are constructed by plotting depth versus flow on log scales (see Figure 11) since depth and flow can be related by an exponential equation of the following form:

$$d = aQ^b$$

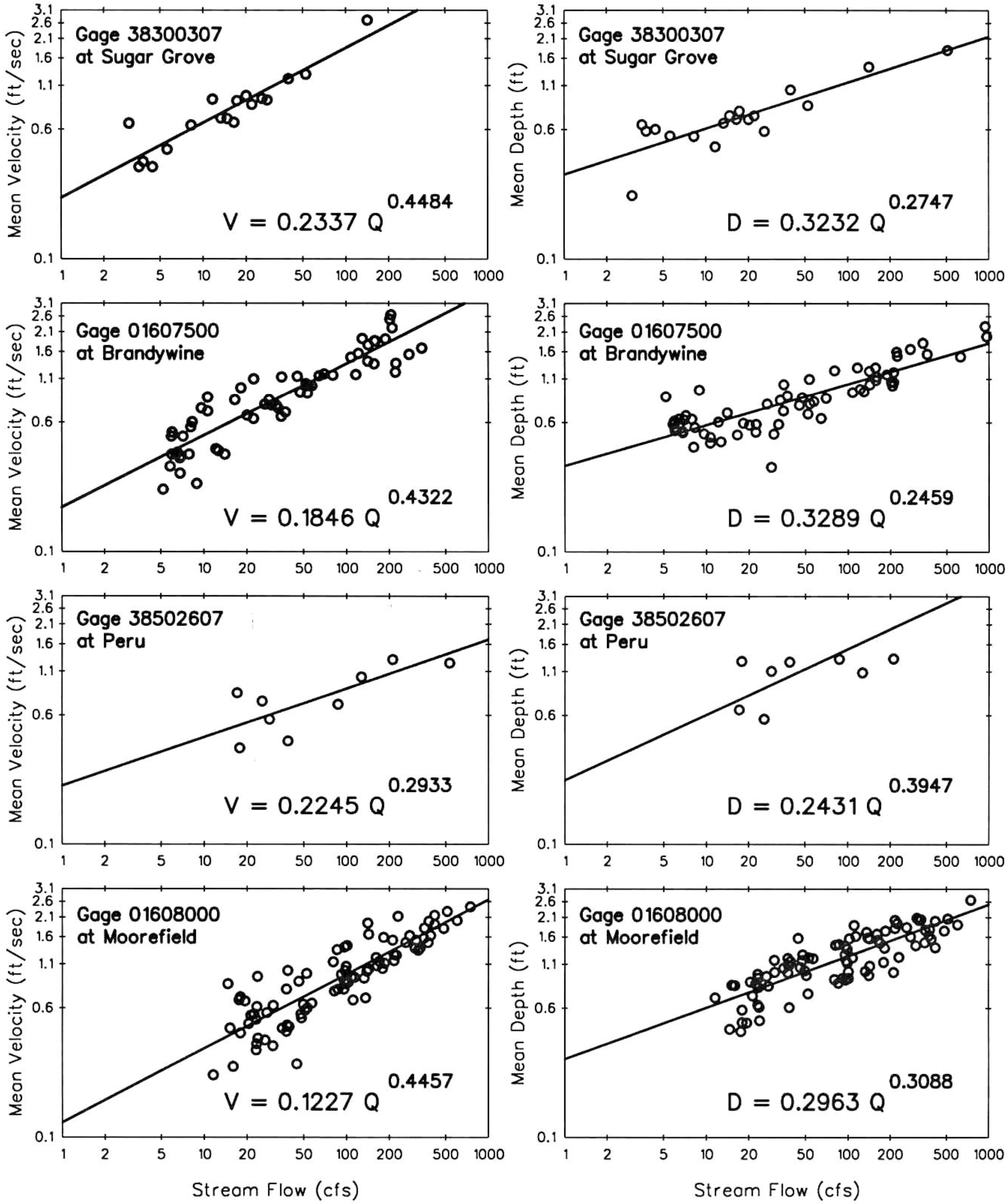
Where: d = water depth
Q = flow
a = coefficient of depth-flow relationship
b = exponent of depth-flow relationship

The coefficient a and exponent b are determined from the intercept and slope of the log-log plot (see Figure 11). Similar relationships can be developed for velocity and width as functions of flow. Considerable hydraulic geometry data are available from:

1. USGS, especially new gauging stations.
2. U.S. Army Corps of Engineers (especially near reservoirs).
3. Federal Emergency Management Agency (FEMA) flow insurance studies.
4. National Weather Service forecasting centers.

In areas where the stream bed varies with time, it is important to use the most current geometry data. When data are not always readily available for small streams and rivers, extra effort may be required in contacting the USGS field offices to get the raw data.

Figure 11. Velocity versus Flow and Depth versus Flow in the South Fork South Branch Potomac River (Lung 2001)



6.3.4 *Outfall and Diffuser Information*

Required information on the diffuser includes the following:

1. Depth of the ports (or pipe depth and riser height).
2. Size(s) and number of ports.
3. Whether the ports are bell-mouthed or sharp-edged.
4. Spacing and orientation of the ports along the diffuser.
5. Orientation of the diffuser to the ambient current and of the ports to the diffuser.
6. Distance from the shore to the first port.

7.0 GLOSSARY

Beneficial Use. Any of the various uses which may be made of the water of Idaho, including, but not limited to, aquatic life, domestic water supplies, industrial water supplies, agricultural water supplies, navigation, recreation in and on the water, wildlife habitat, and aesthetics. The beneficial use is dependent upon actual use, the ability of the water to support a non-existing use either now or in the future, and its likelihood of being used in a given manner.

Bioaccumulation. The process by which a compound is taken up by and accumulated in the tissues of an aquatic organism from the environment, both from water and through food.

Bioaccumulation Factor (BAF). The ratio of a substance's concentration in tissue versus its concentration in ambient water, in situations where the organisms and the food chain are exposed.

Bioconcentration. The process by which a compound is absorbed from water through gills or epithelial tissue and is concentrated in the body.

Bioconcentration Factor (BCF). The ratio of a substance's concentration in tissue versus its concentration in ambient water, in situations where the food chain is not exposed or contaminated.

Buoyancy. The upward force on an object produced by the surrounding fluid (i.e., a liquid or a gas) in which the object is fully or partially immersed, due to the pressure difference of the fluid between the top and bottom of the object. In mixing zone analyses, buoyancy refers to the upward force of the effluent plume in the receiving water due to density differences.

Coanda attachments. A dynamic interaction between the discharge plume and the water bottom that results from the entrainment demand of the effluent jet itself and is due to low pressure effects.

Criterion Continuous Concentration (CCC). The 4-day average concentration of a toxic substance or effluent which ensures adequate protection of sensitive species of aquatic organisms from chronic toxicity resulting from exposure to the toxic substance or effluent. CCC is synonymous with the chronic criterion for toxins.

Criterion Maximum Concentration (CMC). The maximum instantaneous or 1-hour average concentration of a toxic substance or effluent which ensures adequate protection of sensitive species of aquatic organisms from acute toxicity resulting from exposure to the toxic substance or effluent. CMC is equivalent to the acute criterion.

Designated Beneficial Use or Designated Use. Those beneficial uses assigned to identified waters in Idaho Department of Environmental Quality Rules *Water Quality Standards* (IDAPA 58.01.02.110 through 02.160), whether or not the uses are being attained.

Dilution Factor. The available dilution in a receiving stream. The dilution factor is calculated by dividing a proportion (typically 25%) of the receiving stream's critical flow by the effluent discharge flow.

Effluent Limitation. The highest amount of pollutant concentration or mass that can be discharged from a point source into waters of the U.S. Effluent limitations can be expressed as single measurements (instantaneous or daily maximums) or as averages over a given period of time (daily, weekly, or monthly averages).

ESA-Listed. An animal or plant species that has been identified by the U.S. government as endangered or threatened under the Endangered Species Act.

Essential Fish Habitat (EFH). Those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH, "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

EFH has been designated for the 83 species of Pacific Coast groundfish, three species of salmon, and five species of coastal pelagic fish and squid that are managed by the Pacific Fishery Management Council. The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires Federal agencies to consult with National Oceanic and Atmospheric Administration (NOAA) Fisheries on actions that may adversely affect EFH.

Existing Beneficial Use or Existing Use. Those beneficial uses actually attained in waters on or after November 28, 1975, whether or not they are designated for those waters in Idaho Department of Environmental Quality Rules *Water Quality Standards* (IDAPA 58.01.02).

Harmonic Mean Flow. The number of daily flow measurements divided by the sum of the reciprocals of the flows (i.e., the reciprocal of the mean of reciprocals).

Index of Biological Integrity (IBI). A synthesis of diverse biological information which numerically depicts associations between human influence and biological attributes. It is composed of several biological attributes or "metrics" that are sensitive to changes in biological integrity caused by human activities. The multi-metric (a compilation of metrics) approach compares what is found at a monitoring site to what is expected using a regional baseline condition that reflects little or no human impact

Jet Momentum. As it relates to mixing zone analyses, jet momentum refers to the initial momentum flux caused by high velocity injection of effluent into the receiving water.

Lethal Concentration. The point estimate of an effluent concentration that would be lethal to a given percentage of test organisms during a specified period. For example, the lethal concentration fifty (LC_{50}) is the concentration of effluent at which 50% of test organisms die.

Lowest Observed Effects Concentration (LOEC). The lowest tested concentration of an effluent at which adverse effects are observed on the aquatic test organisms at a specific time of observation. The LOEC is determined using hypothesis testing.

Mixing Zone. A defined area or volume of the receiving water surrounding or adjacent to a wastewater discharge where the receiving water, as a result of the discharge, may not meet all applicable water quality criteria or standards. It is considered a place where wastewater mixes with receiving water and not a place where effluents are treated.

Momentum-dominated Near-field (MDNF). The immediate area around the discharge point where mixing occurs due to the velocity/momentum of the discharge.

Nephelometric Turbidity Unit (NTU). A measure of turbidity based on a comparison of the intensity of the light scattered by a sample under defined conditions with the intensity of the light scattered by a standard reference suspension under the same conditions.

No Observed Effect Concentration (NOEC). The highest tested concentration of an effluent at which no adverse effects are observed on the aquatic test organisms at a specific time of observation. The NOEC is determined using hypothesis testing.

1Q10. The 1Q10 is the lowest 1-day average flow that occurs (on average) once every 10 years.

Outstanding Resource Water (ORW). A high quality water, such as water of national and State parks and wildlife refuges and water of exceptional recreational or ecological significance, which has been designated by the legislature and subsequently listed in IDAPA 58.01.02. An ORW constitutes an outstanding national or State resource that requires protection from point and nonpoint source activities that may lower water quality.

Plume. The physical area within the water body where the effluent mixes with the receiving water and there is a distinguishable difference from the ambient water conditions.

Presumed Beneficial Use or Presumed Use. Those beneficial uses (cold water aquatic life and primary and secondary contact recreation) that are presumed to be supported in waters that do not have designated beneficial uses (IDAPA 58.01.02.101.01.a).

Primary Contact Recreation. Recreational activities involving immersion in water or where ingestion of water is likely to occur, such as swimming, water skiing, skin diving, and kayaking.

Public Swimming Beach. Areas identified by features such as signs, swimming docks, diving boards, slides, boater exclusion zones, map legends, fee collection for beach use, or any other unambiguous invitation to public swimming.

Reasonable Potential Analysis (RPA). The analysis conducted by the permitting authority to determine whether a discharge has “reasonable” potential to cause an excursion above applicable water quality criteria. The analysis must consider all of the factors listed in 40 CFR 122.44(d)(1)(ii). An RPA is also known as a reasonable potential to exceed (RPTE) evaluation.

Reference Dose (RfD). An estimate of the daily exposure of a substance to human population that is likely to be without appreciable risk of deleterious effect during a lifetime.

Secondary Contact Recreation. Recreational uses where immersion or ingestion of water is unlikely to occur, such as fishing, boating, and wading.

7Q10. The lowest average seven consecutive day low flow that occurs (on average) once every 10 years.

Special Resource Water (SRW). Those specific segments or water bodies which are recognized as needing special protection to preserve outstanding or unique characteristics or maintain current beneficial use. Idaho SRWs are listed in IDAPA 58.01.02.110 through 02.160.

Species of Special Concern. Native species which are either low in numbers, limited in distribution, or have suffered significant habitat losses. The list includes three categories:

- **Priority Species** - species which meet one or more of the criteria above and for which Idaho presently contains or formerly constituted a significant portion of their range.
- **Peripheral Species** - species which meet one or more of the criteria above but whose populations in Idaho are on the edge of a breeding range that falls largely outside the State.
- **Undetermined Status Species** - species that might be rare in the State but for which there is little information on their population status, distribution, and/or habitat requirements.

30Q5. The lowest average 30 consecutive day low flow that occurs (on average) once every five years.

Toxic Unit - Acute (TU_a). The reciprocal of the effluent concentration that causes 50% of organisms to die by the end of the acute exposure period.

Toxic Unit - Chronic (TU_c). The reciprocal of the effluent concentration that causes no observable effect on test organisms by the end of the chronic exposure period.

Toxic Units - (TU_s). A measure of toxicity in an effluent as determined by the acute toxic units or chronic toxic units measured.

Water Column. A hypothetical cylinder of water from the surface of a water body to the bottom, within which physical and chemical properties can be measured.

Water Quality-Based Effluent Limitation (WQBELs). Effluent limits that have been developed to ensure compliance with applicable water quality criteria.

Water Quality Standards. Regulations consisting of designated uses, criteria to protect those uses, an antidegradation policy, and various optional elements (e.g., a mixing zone policy and variance policy) geared toward protecting the quality of waters of the U.S. Idaho’s water quality standards are codified in IDAPA 58.01.02.

Whole Effluent Toxicity (WET). The aggregate toxic effect of an effluent measured directly with a toxicity test.

Zone of Initial Dilution (ZID). An area within a DEQ-authorized mixing zone where acute criteria may be exceeded. This area should be as small as practicable and assure that drifting organisms are not exposed to acute concentrations for more than one hour more than once in three years. The actual size of the ZID is determined by DEQ for a discharge on a case-by-case basis, taking into consideration mixing zone modeling and associated size recommendations and any other pertinent chemical, physical, and biological data available.

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APPENDIX A. CROSS-REFERENCE OF IDAPA MIXING ZONE RULES AND MANUAL SECTIONS

IDAPA Section	Regulatory Requirement	Mixing Zone Manual Section
58.01.02.051	Includes the State’s anti-degradation policy.	2.1 and 2.7
58.01.02.060.01	Establishes that DEQ must conduct a biological, chemical, and physical appraisal of the mixing zone; consult with the discharger; and where possible, determine the mixing zone size.	Throughout the document, specifically 2.0
58.01.02.060.01.a	Indicates that the discharge to the mixing zone should be through a submerged pipe, conduit, or diffuser.	2.6
58.01.02.060.01.b	Indicates that the mixing zone should be located so it will not cause unreasonable interference to designated uses.	2.0
58.01.02.060.01.c	Indicates that when two or mixing zones are required, the combined mixing zones should not exceed the size and volume necessary for a single mixing zone.	2.5.3
58.01.02.060.01.d	Allows multiple mixing zones for a single discharge for each pollutant or group of pollutants.	2.5.3
58.01.02.060.01.e.(i)	Indicates that the cumulative width of mixing zones in flowing waters should not exceed 50% of the stream width.	2.5.1
58.01.02.060.01.e.(ii)	Indicates that the width of a mixing zone in flowing waters should not exceed 25% of the stream width or 300 meters plus the horizontal length of the diffuser.	2.5.1
58.01.02.060.01.e.(iii)	Indicates that a mixing zone in flowing waters should be no closer to the 7Q10 shoreline than 15% of the stream width.	2.5.1
58.01.02.060.01.f.(i)	Indicates that a mixing zone in a lake or reservoir should not cover more than 10% of the surface area.	2.5.2
58.01.02.060.01.f.(ii)	Indicates that adjacent mixing zones in a lake or reservoir should be no closer than the greatest horizontal dimension of any of the individual mixing zones.	2.5.2
58.01.02.060.01.g	Indicates that water quality within the zone of initial dilution and chronic mixing zone may exceed acute and chronic water quality criteria, respectively.	2.1.2
58.01.02.060.01.h	Indicates that concentrations within a mixing zone should not exceed the 96-hour LC_{50} for biota significant to the receiving water’s aquatic community.	2.3.5
58.01.02.060.02	Describes mixing zone procedures for ORWs.	2.7
58.01.02.210.01	Includes criteria for toxic substances for aquatic life, recreation, and domestic water supply use.	2.1, 2.2, and 2.3
58.01.02.210.03(a)	Indicates that criteria apply at the appropriate locations specified within or at the mixing zone boundary.	1.0
58.01.02.210.03(b)	Defines the flow values (e.g., 7Q10 and 30Q5) to be used in mixing zone analyses, based on the designated use and type of criteria.	2.5.1
58.01.02.250	Includes aquatic life criteria for other pollutants, including ammonia, pH, temperature, dissolved oxygen, turbidity, and dissolved gas.	2.1 and 2.3

IDAPA Section	Regulatory Requirement	Mixing Zone Manual Section
58.01.02.251.01	Defines the bacteria criteria that apply for protection of recreation uses.	2.2.2
58.01.02.401.01 through 401.03	Includes criteria for temperature, turbidity, and chlorine that apply to wastewater discharges.	2.3

APPENDIX B. MIXING ZONE REQUEST FORM

MIXING ZONE REQUEST FORM

THE FOLLOWING INFORMATION SHOULD BE PROVIDED, AS APPROPRIATE, IF REQUESTING A MIXING ZONE. *To determine what is appropriate, please see the document detailing the level of analysis and data inputs. The burden of proof for justifying a mixing zone through demonstrating compliance with the requirements of IDAPA 58.01.02.060 rests with the applicant. DEQ may request additional information if necessary. Discharges without mixing zones must meet State water quality standards at the end of pipe.*

GENERAL INFORMATION

Applicant Information					
First Name:		Last Name:			
Title:					
Street Address:					
City:		State:		Zip:	
Phone #:		Fax #:			
Email:					

Facility Information					
Name:					
Street Address:					
City:		State:		Zip:	
Phone #:		Fax #:			

MIXING ZONE INFORMATION

Level of Analysis: ☐ Level 1 ☐ Level 2 ☐ Level 3 ☐ Level 4
List pollutants for which mixing zone is requested (separated by a comma):
Map: *Attach a topographic map showing location of the discharge(s),other NPDES discharges, drinking water intakes, spawning habitat, and recreation access to the water body (boat ramps, public swimming beaches).*

Outfall Information			
Latitude/Longitude of Outfall(s) in **either** *decimal degrees* **or** *degrees, minutes, seconds*			
Latitude:		Longitude:	
Lat/Long Coordinate Source: ☐ Internet ☐ Map ☐ GPS/Survey* *Identify DATUM used:			
Diameter of Port (m):		Distance from nearest bank (m):	
Height of outfall above stream bottom (m):		Horizontal angle (σ):	
Diffuser? ☐ YES ☐ NO *If yes, answer questions below, as appropriate.*			
Length of diffuser (m):		Distance from nearest bank to first port (m):	
Number of ports:		Distance from nearest bank to last port (m):	
Distance between ports (m):		Port vertical angle (θ):	
Angle between diffuser line and ambient current (γ):			
Angle between port centerline projection and diffuser axis (β):			

Effluent Information			
Flow rate (cfs):		Velocity (ft/s):	
Pollutant Concentrations: *Attach a list of pollutant concentrations expected/measured in outfall*			

Receiving Water Body Information						
Stream Name:		Tributary to:				
Beneficial Uses (check all that apply): Aquatic Life*: ☐ COLD ☐ WARM ☐ SC ☐ MOD ☐ SS ☐ NONE * COLD = cold water; WARM = warm water; SC = seasonal cold; MOD = modified; SS = salmonid spawing; NONE = Use Unattainable Contact Recreation: ☐ Primary ☐ Secondary Water Supply: ☐ Domestic						
Is this a special resource water (SRW)? ☐ YES ☐ NO						
Is there a public swimming beach near the discharge? ☐ YES ☐ NO If yes, distance from the outfall (m): ☐ upstream ☐ downstream						
Is there a surface drinking water intake near the discharge? ☐ YES ☐ NO If yes, distance from the outfall (m): ☐ upstream ☐ downstream						
Does salmonid spawning occur near the discharge? ☐ YES ☐ NO If yes, distance from the outfall (m): ☐ upstream ☐ downstream						
List any threatened or endangered species or species of special concern that occur in the vicinity of the discharge:						
Critical Flows (cfs)	7Q10:		1Q10:		*Other* :	
	30Q5:		Harmonic mean:			
Critical Flow source:						
Channel depth (ft):		Channel width (ft):				
Pollutant concentrations: *Attach a list of background pollutant concentrations, if available. Include the source of information.*						
Describe any available biological data *(attach additional sheets if needed):*						

Mixing Zone Size & Configuration							
% of flow:		Dilution factor:		Width (m):		Length (m):	
Is this a shore hugging plume? ☐ YES ☐ NO							

Model Information (Levels 2, 3, 4)
On an attached sheet, describe the input values not included on this form, the assumptions, and the outcome of the model used.

CERTIFICATION *I certify that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained herein, I believe that the information is true, accurate, and complete.*			
Signature:		Date:	
Printed Name:		Title:	

APPENDIX C. LEVEL OF ANALYSIS AND DATA INPUTS

Data Description	Analysis Level			
Outfall Information	1	2	3	4
Outfall Location *(estimate from 1:24K topographic map or measure with a GPS receiver. When measured then provide the datum)*	E	M	M	M
Map	P	P	P	P
Photographs of the outfall and the vicinity of the outfall	O	O	P	P
Distance from nearest bank to discharge (m)	O	E	M	M
Height of outfall above stream bottom (m)	O	E	M	M
Diameter of port (m)	O	E	M	M
Discharge horizontal angle (σ)	O	M	M	M
Diffuser:				
Length of diffuser (m)		E	M	M
Distance from nearest bank to first port (m)		E	M	M
Distance from nearest bank to last port (m)		E	M	M
Total number of ports		E	M	M
Distance between ports (m)		E	M	M
Port vertical angle (θ)		E	M	M
Angle between diffuser line and ambient current (γ)		E	M	M
Angle between port centerline projection and diffuser axis (β)		E	M	M
Effluent Information				
Flow rate (MGD) and/or velocity (m/s)	E	E	M	M
Pollutant concentrations	P	P	P	P
Receiving Water Body Information				
Critical flow (cfs) or velocity (f/s)	E	E	E/M	M
Channel depth (m)		E	E/M	M
Channel width (m)		E	E/M	M
Channel slope (degrees)		E	E/M	M
Manning's roughness coefficient		E	E	E
Ambient concentrations for pollutants a mixing zone is requested		E	E/M	M
Model Information				
Model used		P	P	P
Basis for model selection		P	P	P
Mixing zone configuration/location		P	P	P
Model Results table		P	P	P

P = provide; E = estimate; M = measurement (field or engineering plans); O = optional

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APPENDIX D. ANALYTICAL SOLUTIONS

Fischer et al. (1979) presented the following two-dimensional mass transport model for ambient-turbulence mixing in rivers:

$$C(x,y)=\frac{M}{du(4\pi D_y x/u)^{1/2}}e^{\frac{-y^2}{4D_y x}} \qquad \text{(Equation D-1)}$$

Where: C = concentration at any given location

M = mass discharged / unit time

d = average depth in the river

u = average velocity in the river

π = pi = 3.1416

D_y = dispersion coefficient across the river

x = distance from the outfall in the longitudinal direction

e = base of the natural logarithm = 2.7183

y = distance from the outfall in the lateral direction

Lung (1995) developed a technical approach for applying Equation E-1 to the James River Estuary in Virginia to address the acute WET of a municipal plant wastewater discharge. The technical information has been approved by EPA Region III in Philadelphia. A copy of the computer model, based on the analytical solutions (Equation D-1), in addition to user instructions is available from DEQ on-line at: http://www.deq.idaho.gov/water/data_reports/surface_water/monitoring/mixing_zones.cfm.

The key model parameters in Equation D-1 are the transverse dispersion coefficients. See Appendix F for ways of independently deriving their values.

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APPENDIX E. CALCULATING MOMENTUM FLUX AND INITIAL DILUTION

E.1 Momentum Flux of Wastewater Flow

It is useful to quantify the momentum flux and buoyancy flux of the wastewater discharge as part of the model selection process. Consider a momentum jet in a cross flow situation. The momentum flux is expressed as:

$M_o = Q_o u_o$

Where: M_o = momentum flux (m^4/s^2)

Q_o = wastewater flow rate (m^3/s)

u_o = velocity of the discharge (m/s)

Next, the momentum length scale is evaluated as follows:

$$l_m = \frac{\sqrt{M_o}}{u_a} \qquad \text{(Equation E-1)}$$

where l_m is a measure of the length at which the momentum-induced velocity equals the ambient river velocity u_a. The jet momentum-dominated regime (or momentum-dominated near-field, MDNF) has a maximum length of l_m, where

$-\frac{y}{l_m} = \frac{y u_a}{\sqrt{M_o}} < 1$ for a jet not yet bent over by ambient current. y is the distance from the outfall to any given location in the receiving water. Note that Equation E-1 is for open water discharge. Both M_o and Q_o values must be doubled for a bank discharge. Equation E-1 therefore yields the spatial domain in length, beyond which mixing in receiving water is governed by the ambient turbulence.

E.2 Initial Dilution Ratio Determination

The following simple calculation shows the computation of initial dilution, if any, provided by a momentum flux. Within an MDNF ($y < l_m$), the dilution ratio of the effluent can be quantified as follows:

$$S = 0.17 \frac{\sqrt{M_o}\, y}{Q_o} \qquad \text{(Equation E-2)}$$

Where: S = dilution ratio

Q_o = wastewater discharge flow

M_o = momentum flux

y = distance in the receiving water from the source

Equation E-2 can be used to calculate the dilution ratio in an MDNF with an applicable range up to a distance of l_m. Note that Equation E-2 is configured for discharge into open waters, e.g., in the middle of a river. The Q_o and M_o values in Equations E-1 and E-2 must be doubled for a discharge from the shore. Examples presented in Section 6.2.3 demonstrate the calculation of momentum flux and dilution ratio for a number of domestic wastewater treatment plant effluents in Alaska.

E.3 Sample Calculations

First, the momentum flux M_o (= $2Q_o$uo) of each discharge is calculated, where Q_o is the discharge flow rate and u_o is the discharge velocity. Note the factor of 2 is used for bank or shoreline (instead of open water) discharges into rivers. Next, l_m (the length of the MDNF), is calculated using Equation E-1, where u_a is the average ambient velocity in the river. Then the dilution factor S at the distance l_m is calculated using equation E-2. Results of this calculation for several sample sites (1-4) are summarized in Table E-1. While the discharge information for Site 4 is not known, its discharge momentum flux is very small.

Table E-1. Discharge and Ambient Water Characteristics

Site	Q_o (MGD / m^3/s)	u_o (m/s)	M_o (m^4/s^2)	Q_a (cfs / m^3/s)	u_a (m/s)	l_m (m)	S (at l_m)
1	1.0 / 0.045	0.198	0.0178	909 / 25.75	0.944	0.141	0.071
2	5.7 / 0.250	0.213	0.1065	4140 / 117.3	0.448	0.728	0.162
3	2.5 / 0.110	0.829	0.1824	30.6 / 0.866	0.609	0.700	0.463
4	0.32 / 0.014	small	Unknown	6.60 / 0.187	0.305	Unknown	Unknown

The analysis above shows that the size of the MDNF is very small (less than 1 m) for the first three sites and expected to be insignificant for Site 4. In addition, the initial dilutions provided by the momentum of the discharges are all below 1, indicating no dilution at all. Therefore, any dilution would be provided by ambient turbulence in the receiving water.

A spreadsheet to perform the above calculations using Equations E-1 and E-2 is available from DEQ on-line at:
http://www.deq.idaho.gov/water/data_reports/surface_water/monitoring/mixing_zones.cfm.

APPENDIX F. DERIVING THE TRANSVERSE DISPERSION COEFFICIENT

The key parameter in far-field mixing zone mass transport analysis is the transverse dispersion coefficient. The commonly used methods to independently quantify or derive the value of the dispersion coefficient are (Lung 2001):

1. Use empirical equations or regression analysis results.
2. Use a mass transport model to back-calculate the dispersion coefficients.
3. Conduct a tracer or dye-dispersion field study.

Method 1 is generally used when there is no data available and employed as a first estimate of the transverse dispersion coefficient. Methods 2 and 3 are designed for use in collecting field data to back-calculate the transverse dispersion coefficient. The transverse dispersion coefficient in rivers may be approximated by the following formulae (Fischer 1979):

$K_y = 0.6du^*$ (Equation F-1)

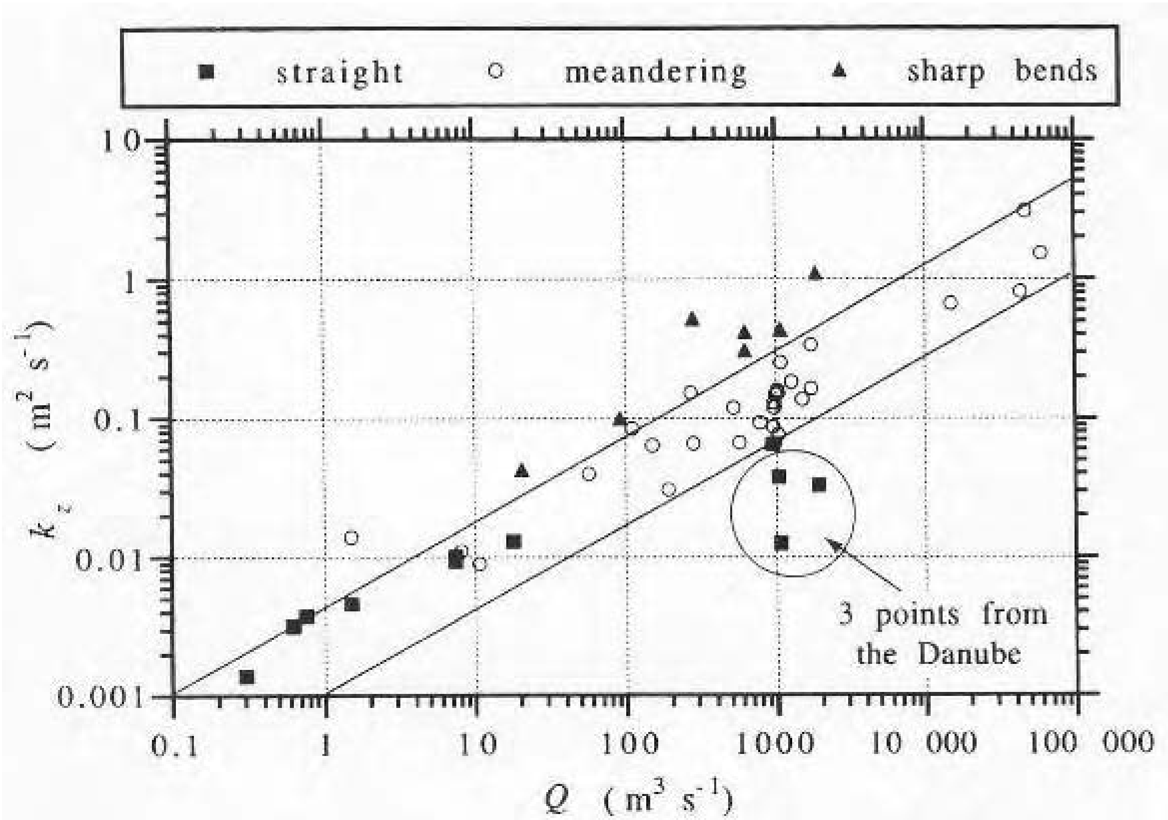
Where: K_y = transverse dispersion coefficient (m^2/s)

d = average depth in river (m)

u^* = average velocity in river (m/s)

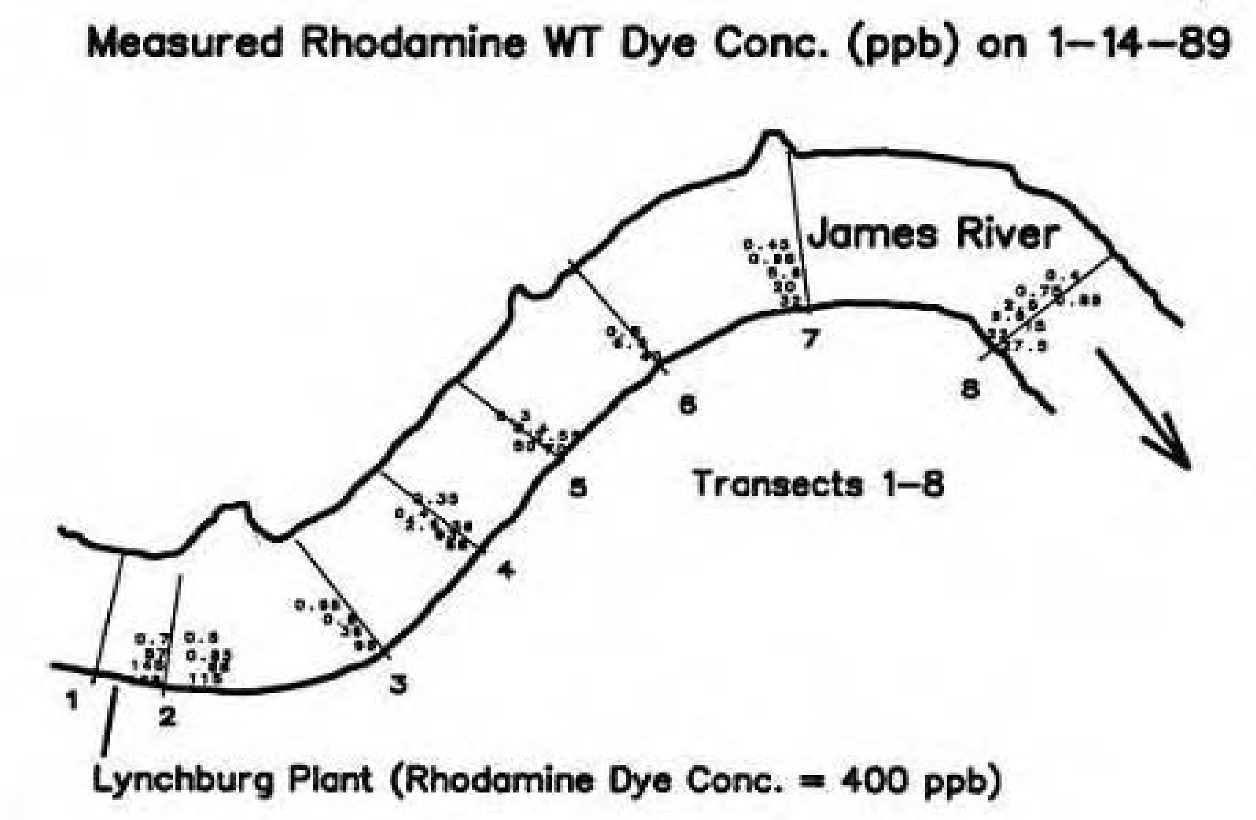
Figure F-1 shows a regression between the transverse dispersion coefficient and river flow as recommended by Rutherford (1994).

Figure F-1. Transverse Dispersion Coefficient versus River Flow (Rutherford 1994)



Of Lung's (2001) three methods listed above, methods 2 and 3 are somewhat related. That is, the dye concentration data collected in the receiving water would be used in calibrating the mass transport model in order to back-calculate the transverse dispersion coefficient in a stream. In a dye dispersion study of the James River, Rhodamine WT dye was continuously injected into the effluent of the wastewater treatment plant at a constant rate (Lung 2001). Figure F-2 displays the dye concentrations along each transect of the river, showing a rapid decline of dye concentration downstream from the outfall.

Figure F-2. Measured Rhodamine WT Dye Concentrations in the Receiving Water (Lung 2001)[1]



While Rhodamine WT red dye is a useful tracer to quantify the transverse dispersion coefficient, specific conductivity serves as a convenient alternate to back-calculate the dispersion coefficient. The specific conductivity levels of a municipal wastewater treatment plant are normally significantly elevated above the ambient level of conductivity in the receiving water. Thus, specific conductivity serves as a perfect tracer in these situations, as shown in Figure G-4 of the case study in Appendix G.

A tracer or dye study can be used to determine the areal extent of mixing in a water body, the boundary where the effluent has completely mixed with the ambient water, and the dilution that results from the mixing. For mixing zone studies in which a discharge is already in operation, tracer studies can be used to determine specific concentration isopleths in the mixing zone that reflect both discharge-induced and ambient-induced mixing. Obviously, if the outfall is not yet in operation, it is impossible to determine discharge-induced mixing by tracer studies. Tracer studies can be used in such situations to determine characteristics of the ambient mixing. For ambient mixing studies, the tracer release can be either instantaneous or continuous. Instantaneous releases are used frequently to measure one-dimensional longitudinal dispersion, but they can also be used to determine transverse mixing in rivers (Holly and Jirka 1986) and lateral and vertical mixing in estuaries, bays, reservoirs, and lakes.

1 The clarity of this figure will be improved in the final document.

A number of references provide information concerning the design, conduct, and analysis of tracer studies for mixing analysis. *Techniques of Water-Resources Investigations of the USGS* (Hubbard et al. 1982) provides the best overview of how to conduct tracer studies. While a number of dye-dispersion studies are listed in EPA 1991, a succinct list of essential items needed for a dye-dispersion study is given below:

1. Flourimeter (configured for use with battery cells and pump for continuous flow operation).
2. Digital current meter.
3. Digital range finder.
4. Dye release setup (including battery cells and a small flow-rate peristaltic pump).
5. Stakes with flags for marking distance along the shore.
6. Boat (to accommodate at least three people on board).
7. Conductivity meter and pH meter.
8. Dilution water.
9. Methanol (to mix with the Rhodamine WT red dye to reach neutral buoyancy).
10. Lab supplies (i.e., buckets, graduated cylinders, beakers, etc.).

APPENDIX G. MIXING ZONE MODELING CASE STUDIES

G.1 CORMIX Modeling of Thompson Creek, Idaho

The Thompson Creek Mining Company (TCMC) in Custer County, Idaho currently discharges runoff into Thompson Creek and Squaw Creek (Figure G-1). The facility is located in the Thompson and Squaw Creek watershed of the Upper Salmon River subbasin. TCMC requested DEQ to authorize mixing zones. A CORMIX modeling study of outfalls 1 and 2 was performed by Environet, Inc. (2000). Results in terms of percent effluents from modeling versus actual data are shown in Figure G-2, both of which display similar spatial patterns and magnitude of mixing. However, measured dilutions showed that beyond initial near-field zones, mixing occurred more rapidly than predicted by CORMIX.

Figure G-1. The Thompson Creek Mine Facility (DEQ 2000)

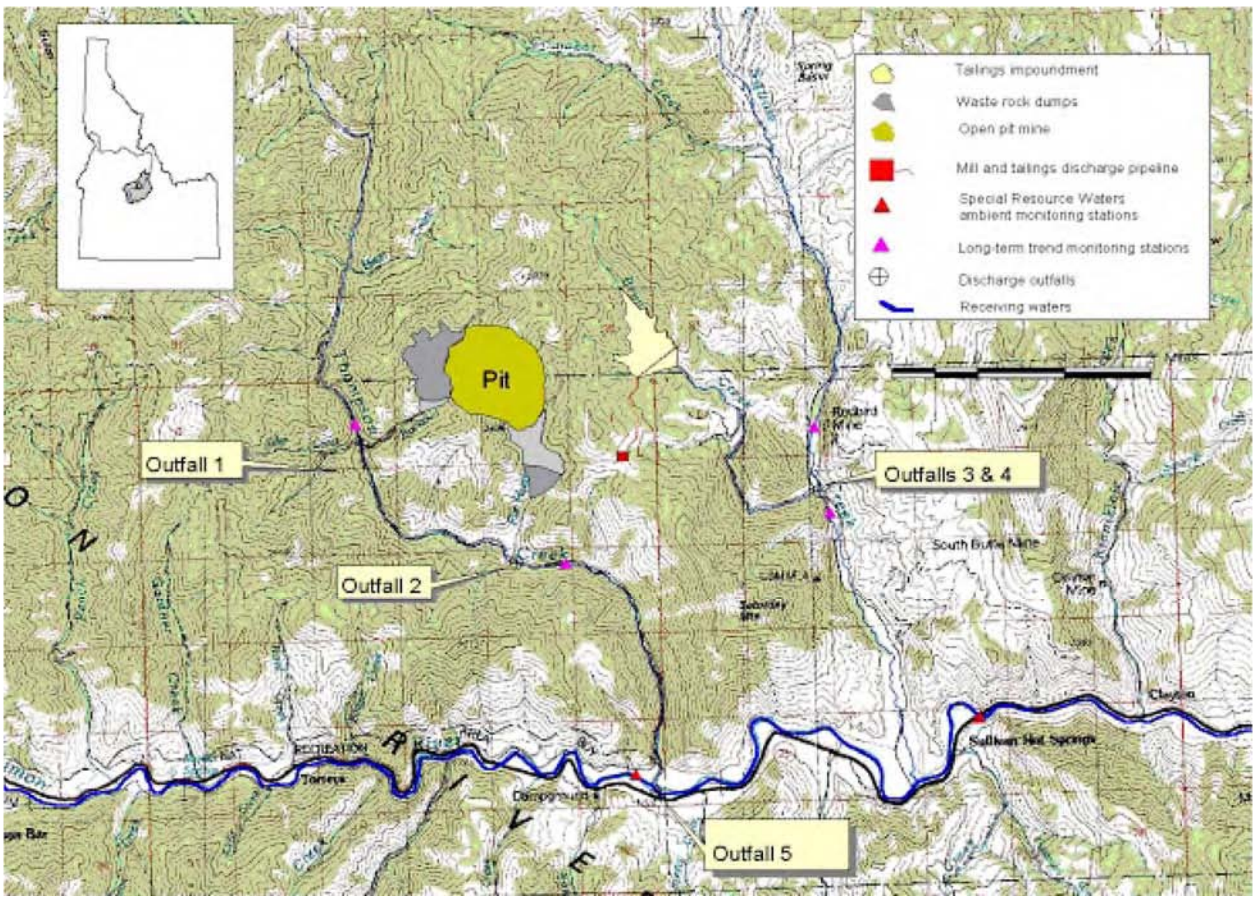
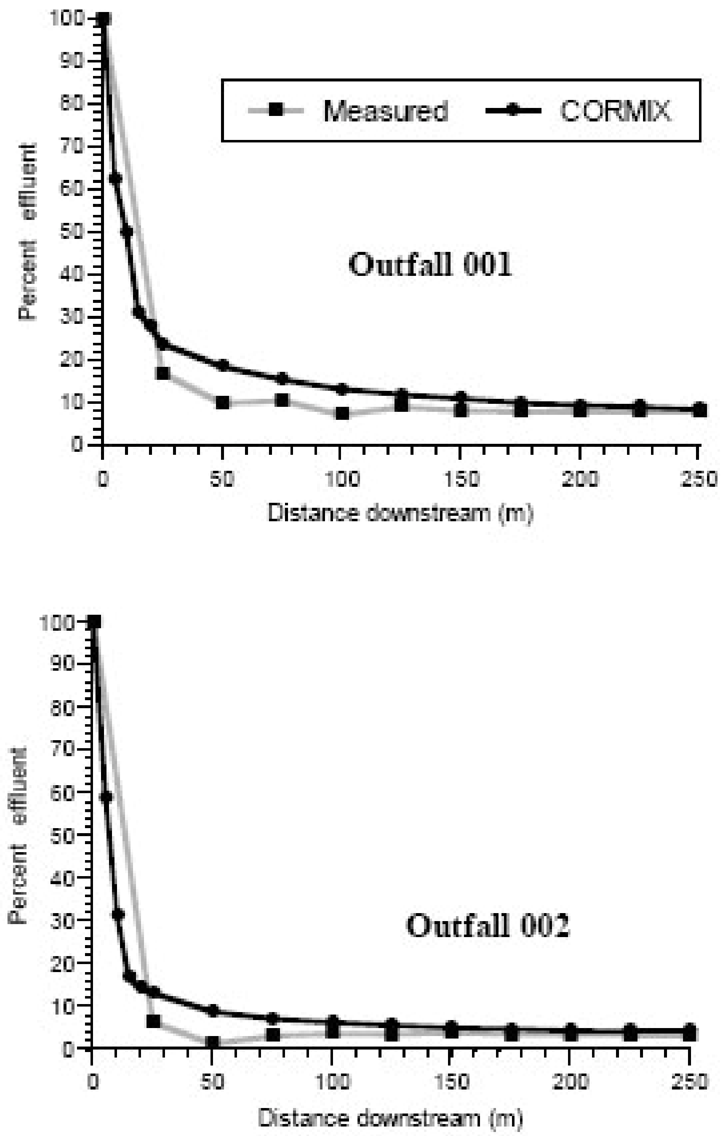


Figure G-2. Modeled Results versus Data of Effluents into Thompson Creek (DEQ 2000)



G.2 Modeling Fecal Coliform Mixing Zone with CORMIX

The following example, which illustrates mixing zone modeling done on discharge with fecal coliform, is from a small intermittent discharge into the Tanana River in Alaska (George 2005). Furthermore, note that fecal coliform is of concern. Idaho does not have numeric criteria for fecal coliform, but instead has numeric criteria for *E. coli*.

The following assumptions were made in performing the modeling for this example:

1. Discharge is at the bank. Assume the pipe lies on the bank at an angle of 45 degrees down and 45 degrees downstream.
2. 30Q10 is used for the months in which the discharge takes place.
3. The discharge occurs in May and October. Use ambient temperatures of 4^{o}C and 6^{o}C, respectively.
4. There is no die-off of fecal coliform bacteria.
5. The background fecal coliform level is zero.
6. The rate of effluent discharge from a pumped lagoon is 420 gallons per minute (gpm) (0.6 MGD) for a 4" pump and 830 gpm (1.2 MGD) for a 6" pump.
7. The effluent limitation is fixed at 1,000,000 fecal coliform units per ml (fc/ml).
8. Fecal water quality standards are 20 fc/100 ml for water supply and 200 fc/100 ml for secondary contact.

Below are more details about the CORMIX modeling of a discharge from a portable pump or bank-side discharge from this example:

1. To model this example as a single port discharge, the discharge will be considered to be in “deep water;” and to be within one-third of the depth of the water from the bottom.
2. When the plume goes out into the channel and the output does not specify that there is bank attachment, BH (an output variable of CORMIX) is the half width of the plume. As soon as there is an interaction of the plume with a bank, BH becomes the full plume width.
3. If the output shows the plume reaching a certain width in the first module, then going back to zero width for the start of the next module, ignore the zero and look at the width of the plume at the end of the module.
4. A comment that the plume “occupies the full region” is a check to see whether there is sufficient buoyancy to lift and re-stratify. If there is not sufficient buoyancy (as in the case of occupying the full region), there is no Phase 2/restratification. The system may then be said to be unsteady and all further calculation ceases because the model needs a steady state condition to compute dilutions. A high jet velocity discharging into a low ambient velocity results in the unsteady conditions. Because CORMIX is unable to continue calculations, the user may then have to do their own mass balance to see what dilution is possible.

Table G-1 summarizes the data used in modeling this example.

Table G-1. Data Used to Model Fecal Coliform Mixing Zone Sample

Pump Size	Receiving Water, River	River Flow (cfs)	Dilution Factor @ 1600m	Fecal coliform @ 10,000 in effluent	Distance to 20 fecal coliform units/100ml	Plume Width
4"	Tanana	6300	360	28	3500m	14 m
6"	Tanana	6300	183	55	>4000m	14 m

G.3 WET Mixing Zone Modeling of a River Discharge

Momentum-induced Initial Dilution Ratio Calculation

To use the simple analytical solution, it is essential to quantify the initial dilution ratio rendered by a discharge's momentum flux. Wastewater flow rates can range from very small (400 gpm) to 10 MGD, and their releases can range from intermittent to steady-state continuous discharges.

The example below is for an effluent discharged from a conventional wastewater treatment plant (Falling Creek wastewater treatment plant) into the James River in Virginia (Lung 1995). The following data is provided:

1. Wastewater flow rate = 10 MGD.
2. Discharge pipe size = 48 in (from the bank of the river).
3. Average ambient velocity near the shore = 0.19 ft/s.

Using the equations in Appendix E yields the following results:

- l_m = 9.1 m, the limit of the MDNF
- a dilution ratio of 1.1 at the edge of the MDNF, indicating almost no dilution offered by momentum-induced mixing

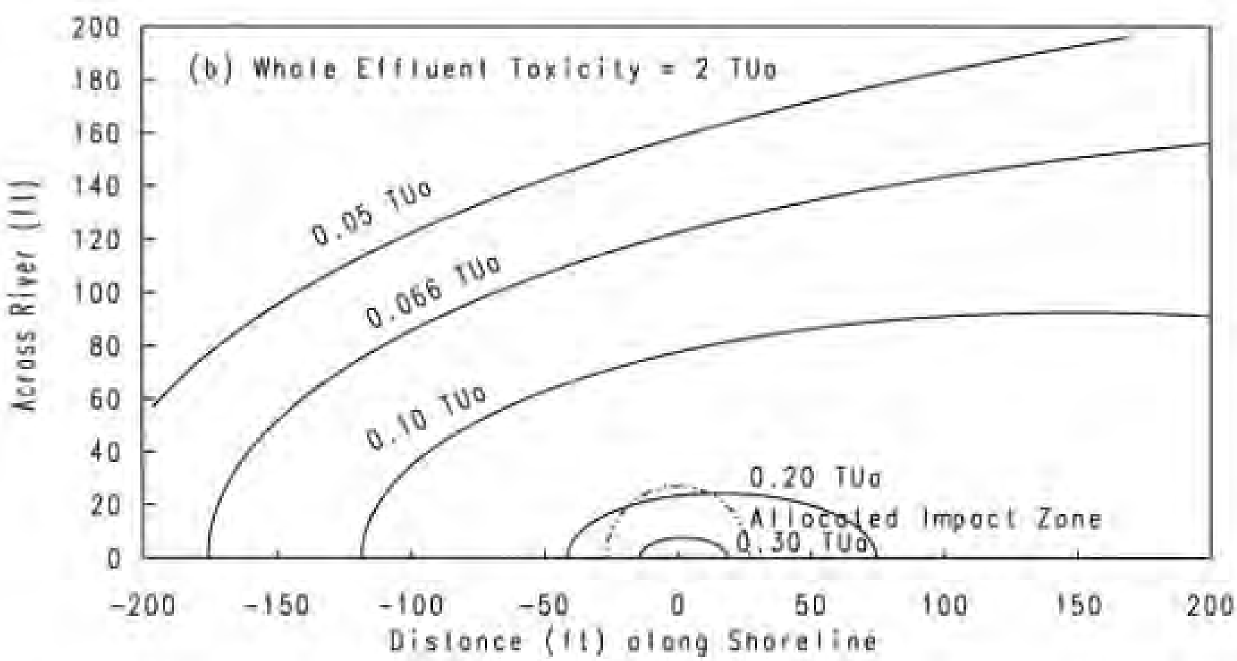
Since the momentum flux associated with this discharge is limited within the MDNF, the mixing would primarily come from ambient turbulence. The analytical solution in Appendix D (see Equation D-1) is used to calculate the far-field mixing (Lung 1995, 2001). Figure G-3 shows the isopleth toxicity contours of various acute toxicity levels associated with an effluent WET of 2 TU_a. Some Federal and state regulatory agencies require that the toxicity level of 0.3 TU_a be met at the edge of the allocated impact zone, with a radius of 27 ft from the outfall (Lung 1995, 2001). For this example, the State regulatory agency originally did not allow a mixing zone, setting an effluent limit of 1 TU_a, which is essentially without any dilution. The modeling results demonstrate that a 50% effluent, or 2 TU_a, can be allowed to meet the 0.3 TU_a at the edge of the allocated impact zone. The analysis was later approved by EPA, and the 1 TU_a effluent limit was removed (Lung 1995).

Running the analytical solution in Appendix D is relatively straightforward. The user only needs to provide the following data:

1. Discharge flow rate (in MGD).
2. Effluent toxicity limit (TU_a or TU_c).
3. Ambient river velocity (ft/s).
4. Longitudinal dispersion coefficient (ft^2/s).
5. Lateral dispersion coefficient (ft^2/s).
6. Average river depth (ft).

Obtaining data for items 1 and 3 is described in the previous section. Item 2, the effluent toxicity limit, is set by the modeler, often with a range. Methods to develop the values for the longitudinal dispersion coefficient D_x (item 4) and lateral dispersion coefficient D_y (item 5) are presented in Appendix F. Item 6, the average river depth at the outfall, can be directly measured on-site.

Figure G-3. WET Mixing Zone Modeling Results Using the Analytical Solution Equation



Data used to generate the modeling results shown in Figure G-3 are listed below:

1. Discharge flow rate = 10 MGD.
2. Effluent acute toxicity = 2 $TU_{a.}$
3. Ambient river velocity = 0.19 ft/s.
4. Lateral dispersion coefficient = 2 ft^2/s.
5. Average river depth = 24.9 ft.

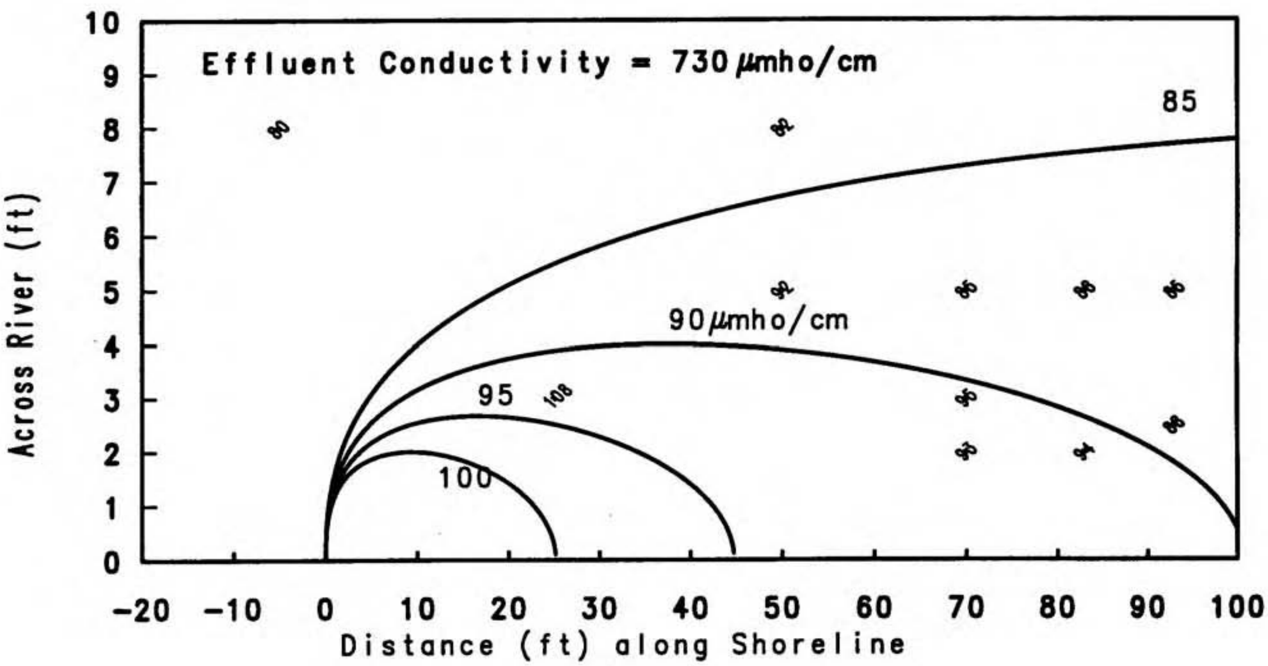
G.4 Conductivity Modeling Using the Analytical Solution

In practice, specific conductivity may be used as a substitute for dye, particularly if a point source discharging into the river has a higher specific conductivity concentration than the ambient levels. This substitution for dye was used with the Burlington Industry, which discharges wastewater into the Banister River near Halifax, Virginia (Lung, 2001). To apply Equation E-1 to the Banister River for the determination of the lateral dispersion coefficient, the following data was used:

1. Total wastewater flow = 0.044 MGD.
2. Effluent specific conductivity concentration = 730 μmho/cm.
3. Ambient river conductivity concentration = 80 μmho/cm.
4. River velocity near the bank = 0.30 ft/s (associated with a river flow of 189 cfs).
5. River depth = 2 ft.

Following a series of model runs using Equation E-1, the modeling results are shown in Figure G-4, where four isopleth conductivity contours (labeled as 85, 90, 95, and 100 micromhos per centimeter [μmho/cm]) are displayed. Also shown for comparison are the measured conductivity levels (in smaller font) in the vicinity of the outfall. The model calculated contours to match the two-dimensional distribution of measured conductivity concentrations near the outfall with a lateral dispersion coefficient of 0.065 ft^2/s. The conductivity plume, which attaches to the shore for over 100 feet, is reproduced by the model results. Approximately 10 feet from the shore in the lateral direction, the conductivity attenuates to approach the ambient level of 80 μmho/cm. Along the shore, the conductivity level approaches the ambient level about 100 feet downstream from the outfall.

Figure G-4. Modeling Conductivity Mixing Zone in the Banister River (Lung 2001)

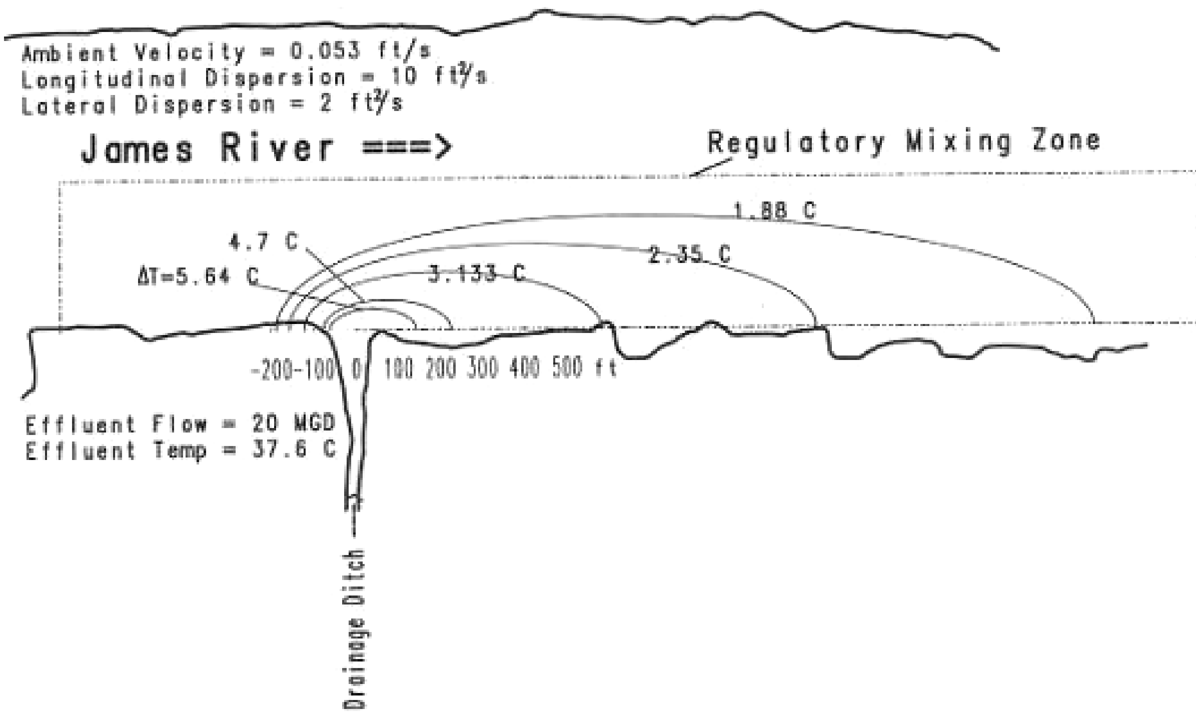


Equation E-1 also provides an independent derivation of the lateral dispersion coefficient as follows. Based on a slope of 0.0003 as measured in the field, Equation F-1 yields a dispersion coefficient value equal to 0.069 ft^2/s, thereby substantiating the value back-calculated by the simple analytical model (Equation D-1).

G.5 Thermal Mixing Zone Modeling

The analytical solution in Appendix D can also be used to address the thermal mixing zone of a heated discharge by simply replacing the pollutant mass (in Equation D-1) with water temperature. Heat loss at the water surface is neglected for a conservative calculation. Figure G-5 shows the thermal plume in temperature isopleth contours from a cooling water flow of 20 MGD and an effluent water temperature of 37.6°C from an industrial facility into the James River in Virginia (Lung 2001). Note that the isopleth contours are the specific water temperature above the ambient water temperature. Key data such as discharge flow rate, effluent temperature, ambient river velocity, and longitudinal and later dispersion coefficients are also displayed. The ambient river velocity is calculated under the 1Q10 (1-day, 10-year minimum statistical flow value) low flow condition.

Figure G-5. Hydrothermal Mixing Zone Modeling Using the Analytical Solution



Data used to generate this result are summarized below:

1. Discharge flow rate = 20 MGD.
2. Effluent water temperature = 37.6°C.
3. Ambient river velocity = 0.053 ft/s.
4. Lateral dispersion coefficient = 2 ft^2/s.
5. Average river depth = 25 ft.